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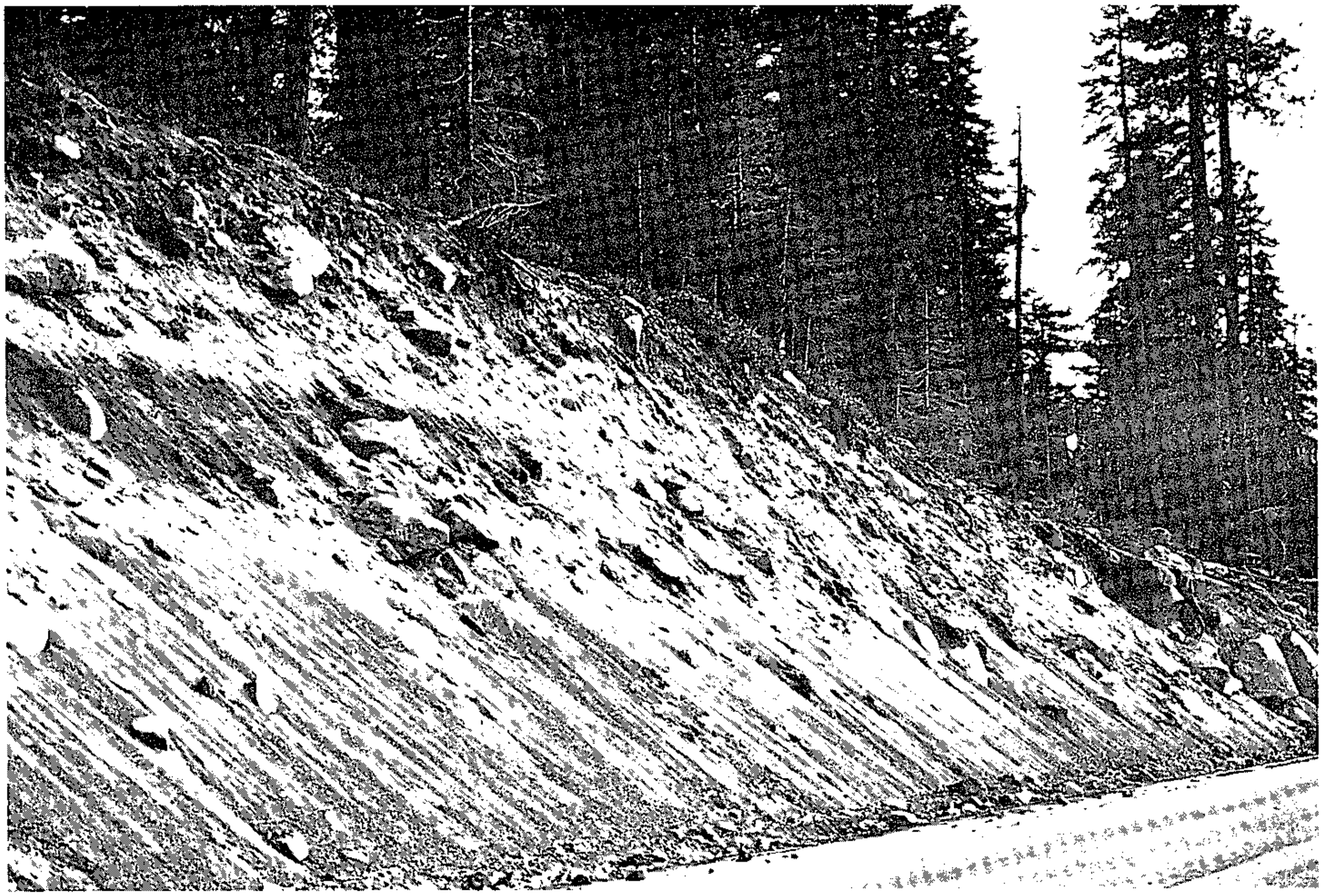
REVEGETATION OF DISTURBED SOILS IN THE TAHOE BASIN

Andrew T. Leiser, James J. Nussbaum,
Burgess Kay, Jack Paul, William Thornhill

75-24



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The authors are: Andrew T. Leiser, Project Leader, Professor, Department of Environmental Horticulture; Jack Paul, Associate Professor, Environmental Horticulture; Burgess Kay, Wildland Seeding Specialist, Department of Agronomy and Range Science; James J. Nussbaum, Research Associate, Environmental Horticulture; William Thornhill, Research Associate, Environmental Horticulture.

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INTRODUCTION

Man-made disturbances of soils in the high Sierra revegetate very slowly. Highway cuts constructed 15-30 years ago are often devoid of vegetation and may erode at rates from 50 to 300 cubic yards or more per acre per year. Adverse effects of this erosion are: siltation of streams and degradation of water quality (particulate and nutrient pollution), lowered aesthetic quality (visual pollution), increased highway hazards from slides and debris on the roadway and increased highway maintenance costs of clean-up of debris from roadway, drainage gutters and culverts.

The objectives of this research project were to: 1) define the kinds of site problems typical of the Tahoe Basin; 2) select most promising plant species for revegetation of typical problem sites; 3) determine cultural requirements (including propagation) for the species selected as suitable for revegetation; 4) study the interaction between various combinations of these plant species; 5) develop methods of establishing grass and woody plants to utilize the best attributes of each to stabilize disturbed areas; 6) determine effects of selected revegetation practices on control of particulate and nutrient erosion; 7) monitor nutrient leaching from selected fertilizers from the coarse soils of the study area and 8) determine the aesthetic results of the woody revegetation plantings.

Objective #6, that of determining effects of selected revegetation practices on control of particulate and nutrient erosion from disturbed mountain soils, was modified by making complete, integrated treatment of selected watersheds which were being monitored by the U.S. Geological Survey (U.S.G.S.) under a separate State-funded study. This monitoring should continue for several years.

We were unable to implement the field portion of the nutrient leaching monitoring we had proposed because of technical difficulties. Greenhouse leaching studies are reported however.

Objective #8, that of determining aesthetic results, was premature in that growth rate of the woody plant materials has been such that a longer period of time would be required to complete this objective. However, the major revegetation effort, in the last 18 months of the project, was done in such a manner that it is felt that the plantings will blend into the disturbed areas quite well with the natural landscape. This monitoring could be done if funds are available.

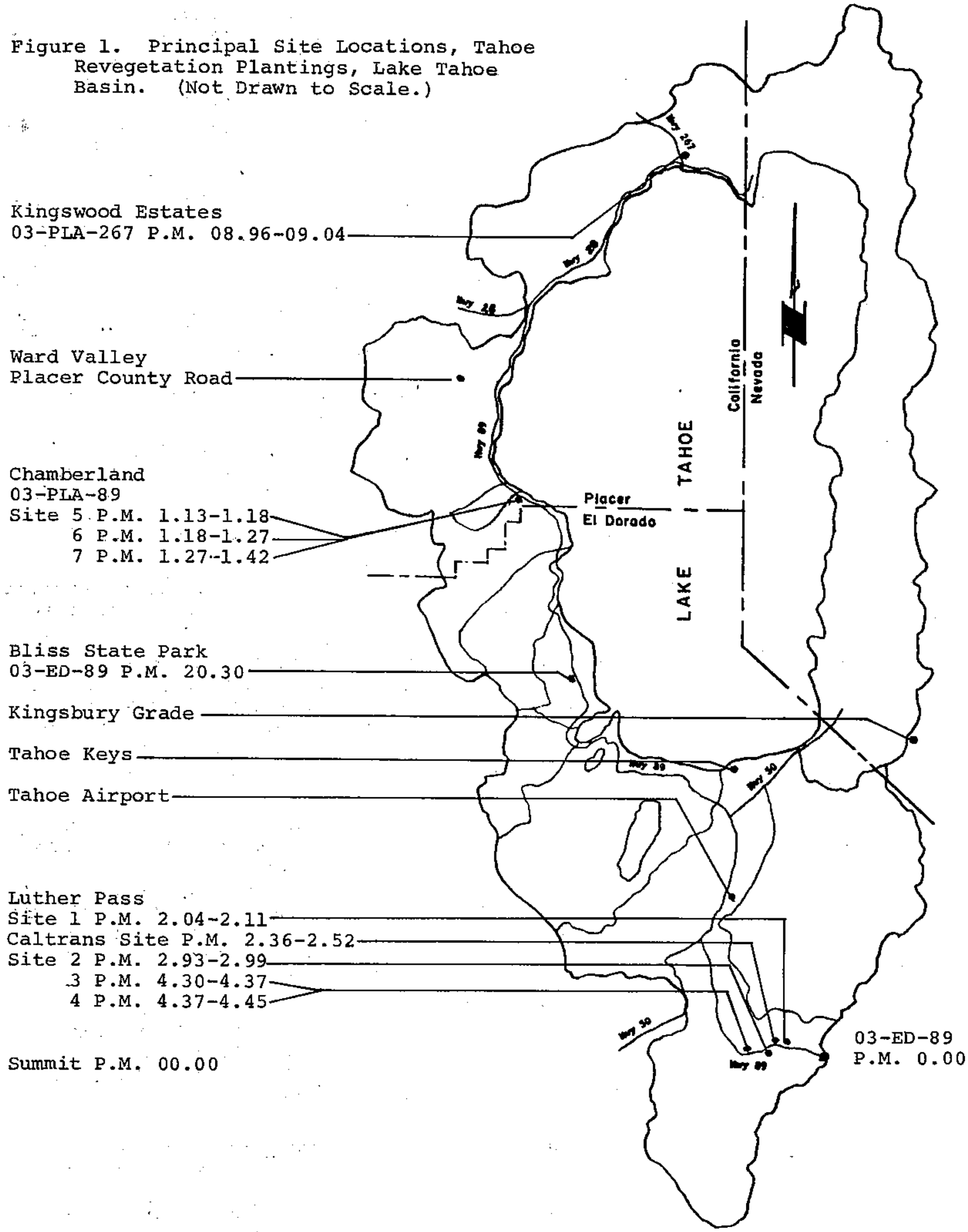
The project, as amended, did limit the major thrust of our effort to investigate the use of native woody shrub species for revegetation of disturbed sites. The research on the use of grasses, mulches and other materials was to support the major effort by learning how to provide interim stabilization for the more permanent woody plants, and to study the effects of these components of the revegetation process on the establishment and performance of the woody species. Again, the estimates of time were optimistic and monitoring of these interactions has just begun.

The study area, the Lake Tahoe Basin, is located in the Sierra Nevada Mountains about 100 miles east northeast of Sacramento, California. Elevations of the planting sites were from approximately 6,300 ft. (near the lake level) to over 7,000 ft. A site location map (Figure 1) identifies these planting sites which were on the south, west and north sides of Lake Tahoe.

Soils on the south and southwest sides of the lake are, for the most part, derived from decomposed granite and those on the northwest and north are of andesite origin. Occasional occurrences of mixed alluvial and glacial deposits are encountered throughout the area. The cut on Luther Pass, 03-ED-89 Post Mile (P.M.) 2.4 planted by District 03 and Transportation Laboratory personnel and the Kingswood Estate site 03-PLA-267 P.M. 09.00 were on what appeared to be alluvial deposits, the former mainly of decomposed granite and the latter a mixture of sand and andesite parent materials.

The microclimates on the planting sites vary greatly because of differences in elevation, aspect and surrounding terrain. Annual variations can also be great. Generally, the planting sites were in an

Figure 1. Principal Site Locations, Tahoe Revegetation Plantings, Lake Tahoe Basin. (Not Drawn to Scale.)



area of 30-45 in. annual precipitation which occurs mostly from October to March, much falling as snow. Summer rains are erratic and consist mostly of scattered thunderstorms, usually of less than 0.25 in. The precipitation record for 1973 on Luther Pass 03-ED-89 Post Mile (P.M.) 2.4 is recorded in Table 1.

TABLE 1. Daily precipitation record, in inches, for Luther Pass, 03-ED-89 P.M. 2.4 for 1973. Data collected by the Environmental Improvement Section, Materials and Research Department, California Division of Highways.

Day	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
1	0	0	0	.10S	0	.06R	0	0	0	0	0	S
2	0	0	.02S	0	0	0	0	0	0	0	0	S
3	0	.01S	0	0	0	0	0	.04R	0	0	0	
4	0	.14S	.44S	0	.06S	0	0	.05R	0	0	0	
5	.18S	.11S	.01S	0	.04S	0	0	0	0	0	0	Amount
6	0	.01S	.03S	0	0	0	0	0	0	0	.98R,S	not
7	0	.36S	.01S	0	0	0	0	0	0	.38R	.41R	reliable
8	0	.01S	.02S	0	0	0	0	0	0	.21R	0	
9	0	0	0	0	0	0	0	0	0	.28R	.50R	
10	.10S	0	.17R,S	0	0	.01R	0	0	0	.04R	.19R	
11	.04R,S	0	.02S	.04S	0	0	0	0	0	0	2.64R	
12	.87R	.01S	.03S	0	.10R	0	0	0	0	0	.04R,S	S
13	.64S	.85S	.09S	.21S	.07R	.02R	0	0	0	0	0	S
14	.32S	.06S	.02S	.06S	0	0	.19R	0	0	0	0	S
15	0	.02S	.01S	0	.05R	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	0	.16S	
17	.39S	0	0	.05R	0	0	0	0	0	0	.78S	
18	0	0	.01S	0	.06R	0	0	0	0	0	.06S	
19	.10S	0	0	0	0	0	0	0	0	.07R	0	
20	.16S	0	0	0	0	0	0	0	.01R	.06R	.13S	
21	.25S	0	0	0	0	0	0	0	0	0	.02S	
22	0	0	.13S	0	.06R	0	0	0	.09R	.33R	0	S
23	.04S	0	.38S	0	0	0	0	0	.01R	.05R	.05S	
24	0	.07S	.01S	0	.02R	0	0	0	0	1.21R	.04S	S
25	0	.13S	.01R	0	0	0	0	0	0	0	.08S	S
26	.13S	.04S	.08R	0	0	0	.09R	.82R	0	0	S	
27	0	.21R	.16S	0	0	0	.13R	.29R	0	0		.14S
28	0	.73S	.08S	0	0	0	.01R	0	0	0	Amount	.12S
29	0		.10S	.06R,S	.03R	0	0	0	0	0	not	0
30	.13S		.11S	0	.04R		0	0	0	0	reliable	0
31	.36S		.08S		.03R		0.10R	0		0		.13S
TOTAL	3.71	2.76	2.02	.52	.56	.09	.52	1.20	.11	2.63	6.08	

R = rain; S = snow.

Severe freezes to 10°F or lower may occur in the fall before snow covers the ground and late spring frosts are common.

Research on similar problem areas was begun earlier for the Department of Transportation, Federal Bureau of Roads at Gold Lake, California and Kingsbury Grade, Nevada. A portion of the findings of this research are included here as background information, to supplement the findings of this research and to indicate the probable application of this research to wider geographic areas.

The first year of the project was spent in evaluating the native plant spectrum for erosion control potential, learning to propagate and grow some of the most promising species and making test plantings of these at various sites in the Tahoe Basin. At the same time grass species and various erosion control chemicals and methods were being evaluated for use for interim stabilization. Test plantings of woody species gave rather strong evidence that it was better to plant in the spring than in the fall and that other measures, in addition to grass overseeding or chemical or wood fiber sprays would be required for interim stabilization. It was concluded that much of the plant losses were due to the instability of the planting sites. Some indication of the potential value of sticking (planting) unrooted cuttings of certain species was obtained in these early tests. Results of these trials were reported in detail in various quarterly progress reports.

Early in 1972 planning was begun for complete, integrated, revegetation plantings of seven cuts on Highway 89 which were being monitored by the U.S.G.S. These were to combine temporary, interim and permanent stabilization and revegetation techniques. This involved the production of about 12,000 transplants and the planning and supervision of mechanical modification of these cuts. Work continued on development of plant propagation and cultural methods of growing plants as well as monitoring of the previous plantings. The installation and preliminary results of these major plantings were detailed in the quarterly progress reports dated September-November 1972, and June-August 1973.

This report includes detailed data taken in the final quarter as well as a summary of the total project. Data taken in June 1974 not only reflect the winter survival of plantings but it was the first full year survival data for the complete revegetation planting of the seven cuts being monitored by the U.S.G.S. Some longer term survival data of other plantings are included. A summary of the overall conclusions of the study and discussion of implementation and feasibility of revegetation of disturbed mountain sites follows. Some of the research findings of this study are presented in the appendices in the form of drafts of proposed research papers. These might also be used in various combinations (possibly with added material) as bulletins, circulars, or an erosion control manual.

INTERIM STABILIZATION TECHNIQUES

Erosion Control Chemicals

In the fall of 1971 a total of 15 erosion control or seeding additive chemicals were compared in replicated tests at Ward Valley, Luther Pass (and on Kingsbury Grade as part of the Federal Bureau of Roads project). None was superior to wood fiber at 1,000 lbs/acre applied with seed and fertilizer. The plastics sometimes reduced plant establishment. A review of these experiments in June 1974 showed differences only at Ward Valley which are presented in Table 2. Grass stands were rated on a 1-10 basis (1 = none, 10 = excellent). The treatment without fertilizer was uniformly poor. Seed and fertilizer alone equaled or exceeded all treatments except 1,000 lbs. of wood fiber/acre. There did not appear to be differences at the other sites. All treatments were effective on the benches at Kingsbury, while none were effective at Luther Pass (03-ED-89 P.M. 1.94), probably because of frost heaving.

TABLE 2. Effect of erosion control chemicals on grass establishment at Ward Valley. Seeded October 1971, evaluated June 1974.

Treatment	Rate	Grass Stand*
Control A	Seed alone, no fertilizer, no cover	4
Control B	Seed + fertilizer only, no cover	7
Wood Fiber	1,000 lb./A, 3,000 gpa water	8
Terra-Krete	180 gpa (6% in 3,000 gpa water)	5
Verdyol Super	79.5 lb./A, + wood fiber 1,000 lb./A, 3,000 gpa water	6
Ecology Control	80 lb./A, + wood fiber 1,000 lb./A, 3,000 gpa water	6
Soil Seal	87.2 gpa, + wood fiber 1,000 lb./A, 6,000 gpa water	4
Curasol AE	90 gpa, + wood fiber 750 lb./A, 3,000 gpa water	5
Terra Tack I	20 lb./A, + ground barley straw 1,000 lb./A, water 1,000 gpa	7
Terra Tack I	30 lb./A in 1,000 gpa water applied over whole straw at 2,000 lb./A	6
Terra Tack I	30 lb./A in 1,500 gpa water	5
Aquatain	130 gpa in 1,000 gpa water	6
Earth-Pac	1 gal/5,000 sq. ft. in 3,000 gpa water	6
SSO	10 gpa	5
Excelsior Erosion Control Blanket		7

*10 = excellent, 1 = none.

Landlock (3M Co Elastomer 23860) was tested at 4 locations in April 1972. Landlock treatments were never better than wood fiber alone at 1,000 lbs/acre at any site. Landlock plots had fewer grass seedlings and the crust formed did not adhere to the slope. (Repeat trials in cooperation with Caltrans, but not part of this contract, at several other locations also resulted in failures.)

Two products which showed promise in tests at the University of California at Davis were applied at Chamberland (03-PLA-89 P.M. 1.18-1.27) in the fall of 1972. Ecology Control and Landlock were compared to wood fiber. All treatments were successful. Wood fiber at 1,000 lbs/acre plus seed and fertilizer was satisfactory. The addition of a chemical did not improve results.

Erosion Control Mats

Excelsior mat or blanket was included with the 1972 erosion control chemical tests to evaluate their usefulness for interim stabilization and showed promise in early evaluations. Therefore, mats were tried again in the fall of 1972 at 03-ED-89 P.M. 4.37-4.45 (Luther Pass) and 03-PLA-89 P.M. 1.27-1.42 (Chamberland). Single and double thickness of a woven paper mat were also compared to excelsior mat and to wood fiber at 1,000 lbs/acre. An average of the results at the 2 sites in July 1973 (Table 3) showed no treatment was an improvement over fiber alone (also see pp. 13 and 26, quarterly progress report, September-November 1973). An evaluation in June 1974 showed hydroseeding superior to excelsior at Chamberland (in 2 of 3 replications) and inferior at Luther Pass (in 2 of 3 replications) for an average of no difference. Excelsior was only slightly better than the single paper mat. Doubling the mat did not improve the results but may have reduced grass establishment.

Slope Serration

The serration of cut slopes, using 3 to 4 ft. horizontal and vertical steps has proven useful in certain highway construction practices. It appeared to have been partially helpful on Kingsbury Grade (Nevada Rte. 19) in decomposed granite rock in allowing the establishment of vegetation on the horizontal portions of the serrations except where the material was too soft and erosion filled the bench, resulting in little or no plant establishment.

TABLE 3. Effect of erosion control mats on grass stand at two locations.[1] Installed fall 1972, rated July 1973 on a 1-10 basis*.

Treatment	Luther Pass	Chamberland	Mean
Hydroseeding + wood fiber, 1000 lbs/A	5	9	7
Hydroseeding + excelsior blanket	7	7	7
Hydroseeding + single paper mat	6	6	6
Hydroseeding + double paper mat	6	4	5

*Rating scale: 10 = excellent, 1 = none.

[1] Luther Pass, 03-ED-89 P.M. 4.37-4.45 and Chamberland, 03-PLA-89 P.M. 1.27-1.42.

Serrations were constructed on two locations in this research; at Bliss State Park (03-ED-89 P.M. 20.3) in a soft decomposed granite rock and on Luther Pass (03-ED-89 P.M. 2.11) in an apparently highly compacted sedimentary deposit. Data included later in this report (pp. 10,11,12,13, T.8,9) show reduced survival on the two sites. The serrations appeared to increase erosion at both sites and the reduced survival was attributed, at least in part, to this increased erosion.

Breast Walls

Breast walls differ from retaining walls in that they are placed against more or less undisturbed earth and receive little force from the earth behind them. These walls were installed on portions of two of the seven cuts on which complete revegetation was attempted. They reduced the effective height of the cuts and allowed a reduction in the slope of the cut after rounding of the top of the cut was completed. They have been perfectly stable through two winters. Because they were installed with considerable batter (back slope), soil-forming material from the cut-rounding operation was back-filled almost to the outer face of the breast walls, there does not seem to have been a problem with rocks catapulting onto the roadway. These breast walls were installed by inexperienced crews and, in spite of instructions to the contrary, the interstices were not always filled and compacted as thoroughly as desirable. Although not done in this research, it is suggested that all interstices be filled with soil material and that pieces of plant material of a species that will root be placed in these interstices. The technique is explained and diagramed in Appendix I. Figure 2 shows breast walls on cut at 03-ED-89 P.M.

Wattling

The use of wattling for stabilization of fill slopes was advocated by Kraebel in 1936 (2). This technique was used in backfill areas on four of the seven cuts prepared in 1972 with outstanding success. During the week of May 21, 1973, Division of Highway personnel from District 03 and from the Transportation Laboratory, placed over 1,100 lineal ft. of wattling on a cut on Luther Pass, 03-ED-89 P.M. 2.32-2.56 with planning assistance by U. C. project personnel (Figure 3). This cut was approximately an acre in area, had surface or subsurface moisture over much of its area, and had been eroding at a rate of about 108 cu yd/yr (1). In addition to the wattling, unrooted willow cuttings approximately 10" x 3/8-3/4" diameter were planted on 2 ft. centers and the slope was seeded with grass (3). This treatment appeared to have almost totally stopped erosion of this cut within one growing season. Actual data for erosion losses for the past winter are not available, however. The original wattling was still stable and growing well following the first winter. This project is summarized in greater detail in Appendix II. Wattling procedures are discussed in detail in Appendix III.

PLANT MATERIALS AND CULTURAL PRACTICES

Miscellaneous Trials

Second year data on some experiments are reported where trends have changed from earlier reports. Unfortunately, such changes are usually negative. First year data on grass transplants and a willow cutting experiment are also reported here.

In 1972, pre-germinated *Quercus vaccinifolia* (huckleberry oak) acorns were planted on 4 sites, Luther Pass 03-ED-89 P.M. 00.95, Bliss State Park 03-ED-89 P.M. 20.30, Ward Valley (County Road) and Kingswood Estates 03-PLA-267 P.M. 09.00 on southwest, east, south and west facing slopes respectively. First season survival ranged from 21 to 66%, with a total of 116 of 300 plants alive (39%) and, because of the low cost and ease of such plantings, was considered a very successful procedure. Data taken on September 16, 1973 indicated that two sites with first season survival of 31 and 66% no longer had any plants and a total of only 19 plants remained alive. On June 4, 1974, only 2 plants could be found (Table 4). Losses are believed to be due, in part, to continued feeding by rodents. Other unknown causes may have contributed to these losses. This plant is a dominant component of vegetation in much of the Tahoe Basin (and other mountain areas) in extremely dry, hot, rocky sites. This fact makes the

Figure 2. Breast walls on Site 3, Luther Pass 03-ED-89. Rocks in center were in original cut.

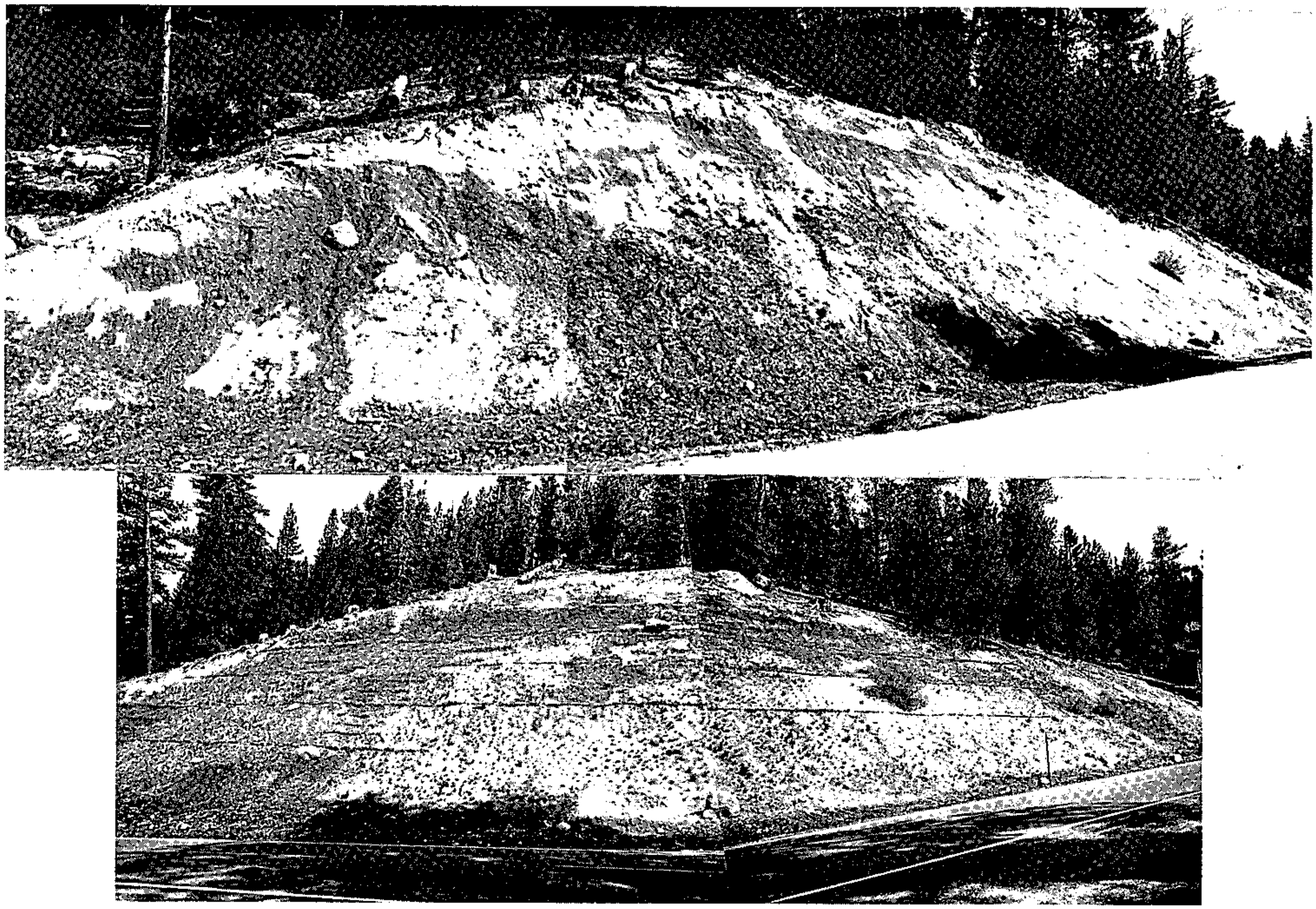


Figure 3. Cut slope at 03-ED-89 P.M. 2.4 before and after revegetation treatment of wattling, planting of unrooted willow cuttings and hydroseeding.

TABLE 4. Stand count of pre-germinated Huckleberry oak (Quercus vaccinifolia) acorns on 4 sites in the Tahoe Basin. Acorns planted in spring 1972.

Location[1]	Planting Date	Number Planted	1972					1973	1974
			6/6	6/28	7/25	8/24	9/27	7/16	6/4
Luther Pass	4/26	100	10	9	23	25	31	0	1
Bliss State Park	5/4	40	28	27	30	26	24	16	0
Ward Valley	4/25	100	25	46	44	28	21	3	1
Kingswood	4/23	60	0	16	25	21	40	0	0

[1]Luther Pass, 03-ED-89 P.M. 00.95; Bliss State Park, 03-ED-89 P.M. 20.30; Ward Valley, County Road; Kingswood, 03-PLA-267 P.M. 09.00.

high second and third year mortality on these research sites puzzling.

Survival data on the early Salix (willow) and Cornus (dogwood) cutting experiments are also brought up-to-date (Table 5). The reduction in survival of unrooted cuttings at all sites was somewhat disappointing. The causes are not all understood although two contributing factors are known. All sites are unstable and even the 1" x 2" survey stake plot markers have eroded off the Luther Pass 03-ED-89 P.M. 00.95 site. A later study has shown that survival is related to cutting size. All of these cuttings were 6-8" tip cuttings of usually less than 1/4" dia. In subsequent experiments 3/8" to 1/2" diameter cuttings, 10" long, have had higher survival rates.

A comparison of cutting size, hormone treatment and fall vs. spring planting of Salix lemmonii was begun in 1972 on Luther Pass 03-ED-89 P.M. 2.36. First year data (Table 6) demonstrated the superiority of fall planting and of cuttings larger than 3/8". Second year data showed a marked decrease in numbers of fall planted cuttings the second winter and almost complete loss of the spring planted cuttings. Some of the loss was attributed to site quality because spring planted cuttings, a few hundred yards away on the Caltrans planted cut at 03-ED-89 P.M. 2.32-2.56, survived quite well. This site, on topsoil, was probably more droughty than the cut. Some of the loss may have been due to the reduced growing season for spring planted cuttings and, thus, a reduced ability to store carbohydrate reserves. The IBA (hormone) treatment did not increase cutting stand.

One of the most difficult areas to revegetate has been the tops of the cuts. A combination of instability plus drought accounts for this fact. Grass establishment by seeding has been particularly poor on this portion of the cuts. However, grass transplants in the spring of 1973 at both 03-ED-89 P.M. 1.94 (Luther Pass) and 03-PLA-89 P.M. 1.27 (Chamberland) showed a high survival rate even though planted at the most difficult top-of-cut position. Survival of the transplants of 'Barton' western wheatgrass, measured June 1974, was 83% at Luther Pass (03-ED-89 P.M. 1.94) and 100% at Chamberland (03-PLA-89 P.M. 1.27). The plants are spreading by rhizomes, especially at the Chamberland site.

This research was expanded in April, 1974 with grass transplant tests at Luther Pass (03-ED-89 P.M. 1.94) with 3 species of rhizomatous wheatgrass, 'Barton' western, 'Sodar' streambank, and 'Topar' pubescent. These were felt to be the 3 most strongly rhizomatous species available commercially. The test compared fertilizing with one gram of nitrogen per hole (as 21-8-8, a combination of slow and fast release nitrogen), and no fertilizer, as well as 2 sizes of peat pots. Observations made on June 20, 1974 indicated the larger peat pots (6 cm x 6 cm) are superior to the smaller (5 cm x 5 cm), and that fertilization is imperative. From one to two inches of

TABLE 5. Survival of Salix and Cornus unrooted cuttings planted at three sites in the Tahoe Basin.

Site[1]:	Luther Pass				Bliss State Park		Kingswood	
Species:	Salix		Cornus		Salix	Cornus	Salix	Cornus
Planting Date:	11/2/71	4/26/72	11/2/72	4/26/72	5/4/72		5/23/72	
Number Planted:	160	160	160	160	38	30	106	36
Dates								
6/6/72	# 72	98	28	67	19	8	-	-
6/28/72	70	88	24	65	15	11	16	6
7/25/72	67	81	18	51	12	5	15	4
8/24/72	58	70	12	32	11	5	15	2
9/27/72	40	46	13	25	11	4	15	2
6/15/73	31	33	1	4	9	2	12	1
6/4/74	30	28	0	2	5	0	12	0

[1]Luther Pass, 03-ED-89 P.M. 00.95; Bliss State Park, 03-ED-89 P.M. 20.3; Kingswood, 03-PLA-267 P.M. 09.00.

TABLE 6. Effects of cutting size and indolebutyric acid on direct stuck Salix lemmonii (willow) cuttings. Data are number of cuttings leafed out. Luther Pass, 03-ED-89 P.M. 2.36. Decomposed granite soil; dry site.

Size in diameter Treatment	Planted 10/72	Planted 5/73	Survival 6/15/73	Survival 7/17/73	Survival 6/74
3/16-1/4 Control	50		23	20	6
3/16-1/4 2000	50		27	17	1
3/8-1/2 Control	50		46	44	23
3/8-1/2 2000	50		39	39	21
3/4-1 Control	50		43	38	11
3/4-1 2000	50		37	34	4
3/16-1/4 Control		50		2	0
3/16-1/4 2000		50		1	0
3/8-1/2 Control		50		13	1
3/8-1/2 2000		50		21	1
3/4-1 Control		50		20	0
3/4-1 2000		50		25	0

Totals: Hormone treatment: Control 41/300, IBA 27/300 — Season: Fall 66/300, Spring 2/300

Cutting diameter: 3/16"-1/4" 7/200; 3/8"-1/2" 46/200; 3/4"-1" 15/200 erosion had occurred on the nonfertilized plots as well as where the fertilized, small pots were used. The pots were exposed 1 to 2 inches. By contrast, there was no erosion on fertilized, large pot transplants. This was attributed to the additional size of the plants in large pots as well as increased vigor due to fertilization. Survival data only two months after planting would be premature. This research should be expanded.

Plots installed on Highway 267 (03-ED-267 P.M. 08.96-09.04) at Kingswood Estates were originally intended to compare fall and spring planting and the effects of supplemental irrigation. Comparisons of irrigation were rendered invalid when lawn irrigation above the cut changed the moisture conditions in the cut. However, comparisons of the season of planting results (Table 7) continue to indicate a distinct advantage for spring planting. Surviving plants are beginning to make a real impact on this cut, both in terms of erosion control and aesthetics.

TABLE 7. Survival of fall 1971 and spring 1972 plantings, non-irrigated and irrigated at Kingswood Estates, Highway 03-PLA-267, P.M. 09.00, on June 5, 1974 (alive/planted)[1].

	Non-Irrigated		Irrigated	
	Fall	Spring	Fall	Spring
Arctostaphylos nevadensis	1/9	1/9	0/9	1/9
Cytisus decumbens	0/9	1/9	1/9	2/9
Artemisia caucasica	0/36	16/36	1/36	8/36
Penstemon newberryi	2/45	37/45	14/45	22/45
Ceanothus prostratus	1/27	5/27	2/27	1/27
Total	4/126	50/126	18/126	34/126
	54/252		52/252	
	106/504			

[1]Data: Surviving/planted.

A planting comparing various transplant container sizes with seeding was made near the top of a decomposed granite rock cut at Bliss State Park 03-ED-89 P.M. 20.30 on May 4, 1972. Species planted were <u>Penstemon newberryi</u>, <u>Ceanothus prostratus</u> and <u>Arctostaphylos nevadensis</u>. This planting was a split-block with 1/2 the plants placed in individual holes or pockets on the cut and 1/2 the plants placed on flat benches created by serrating the slope. The survival data is brought up-to-date in Table 8. Between July 16, 1973 and June 1, 1974, 3 plants were lost from the serrated or benched plot and 2 from the pocket planting. The benches have completely disappeared from erosion. Erosion was less severe in the area where planting was in pockets. In time these plantings may be lost because there are no plantings on the bottom of the slope and under-cutting is beginning to occur. The survival rate of <u>Penstemon newberryi</u>, 50%; 30% and 80% for 2" peat pot, 1" x 6" tar paper tube liners and "gallon" can plants, respectively, planted on the benches was very gratifying for this difficult, top-of-cut site in decomposed granite rock. The survival in the pocket planted are of 90%, 83% and 92%, respectively, for these sized containers was higher than one might expect in a non-irrigated planting on such a harsh site. There was no germination of seed plantings.

Complete, Integrated ("Watershed") Plantings

The complete "watershed" slope treatments installed during the fall of 1972 and spring of 1973 were intended not only to demonstrate the combination of temporary, interim and long term stabilization and revegetation of cuts but were to serve as research plots as well. One objective was to again compare fall and spring planting. Because earlier work had indicated that spring planting was superior to fall planting and because one objective was to obtain overall satisfactory plant density, only about 25% of the

TABLE 8. Survival of plants on benches and in planting pockets at Bliss State Park, 03-ED-89 P.M. 20.30. Planted 5/4/72. Planting site, raw decomposed granite rock.

	Survival								
	5/4	6/6	6/28	7/25	8/24	9/27	7/16/73	6/4/74	Percent
Benched Area									
Penstemon newberryi 2" pp[1]	10	10	9	7	7	8	6	5	50
P. n. 1" x 6"	10	10	9	6	7	7	3	3	30
P. n. gallon	10	10	10	10	10	10	9	8	80
P. n. seed	10	0	0	0	0	0	0	0	0
Ceanothus prostratus 2" pp	10	9	8	7	7	6	1	1	10
C. p. gallon	10	10	10	9	9	9	4	4	40
C. p. seed	10	0	0	0	0	0	0	0	0
Arctostaphylos nevadensis 2" pp	10	7	5	4	3	2	1	0	0
Pockets									
Penstemon newberryi 2" pp	20	20	20	20	20	20	19	18	90
P. n. 1" x 6"	12	12	12	11	10	9	10	10	83
P. n. gallons	12	12	12	12	12	12	11	11	92
P. n. seed	20	0	0	0	0	0	0	0	0
Ceanothus prostratus 2" pp	8	8	7	5	4	3	1	0	0
C. p. gallon	8	8	8	7	7	7	6	6	75
C. p. seed	20	0	0	0	0	0	0	0	0
Arctostaphylos nevadensis 2" pp	0	0	0	0	0	0	0	0	0

[1]pp - peat pot, 1" x 6" = tar paper tubes, gallon = commercial "gallon" can, a crimped #10 can.

total plant materials were fall planted with 75% being planted in the spring. Fall and spring plantings also varied somewhat in the total plant spectrum used because of differences in availability of materials for unrooted cuttings and transplants. Five species of plants in peat pots and two species as unrooted cuttings were planted during both seasons. Two species in peat pots were planted only in the fall and one species only in the spring while five species of unrooted cuttings were planted in the fall only. These plantings were described in detail in progress reports for September-November 1972 and June-August 1973. First season survival data are summarized in June-August and September-November 1973 progress reports.

The pre-planting site preparation, soil types and microenvironment varied from site to site. These factors were representative of the range of preparation, soil types and microenvironments that would be met with on most other highway sites in the Tahoe Basin. However, between site comparisons have little specific meaning.

Individual species were not randomized but were placed on each cut in the microsite for which they were judged best adapted, e.g. species such as *Artemisia tridentata* and *Purshia tridentata* were placed in drier areas and *Salix lemmonii* were planted in wetter areas. Therefore, between species comparisons cannot be made except in a general way.

Several fertilizer comparisons were made on all sites and with all species of transplants common to both planting seasons. These data are presented and discussed in a later section of this report (p. 17,19; Table 15).

The survival data for all sites and species for both planting seasons taken June 4 and 5, 1974 are summarized in Table 9. The survival pattern was little changed from that noted the previous fall although some attrition had occurred. These data pool all sub-plots and certain fertilizer treatments reduced survival appreciably, hence, survival in the best sub-plots was often much higher than the means.

These plantings confirmed earlier findings that spring planting is superior to fall planting. Discussion is confined to comparisons of species planted during both seasons. Of the 1972 fall plantings, only *Penstemon newberryi* transplants and *Salix lemmonii* showed satisfactory survival of 53% and 46%, respectively (after two winters). Survival of other transplants was 0 for *Purshia tridentata*, 0.5% for *Arctostaphylos nevadensis*, 1% for *Artemisia tridentata* and 11% for *Ceanothus prostratus*. None of the *Cornus stolonifera* cuttings survived. Spring, 1973 planted *Penstemon* and *Salix* showed nearly the same survival as for those planted in the fall, 51% and 46% respectively (after one winter). The striking differences were in the survival of the other species. Survival of *Purshia* increased from 0% to 25%, *Arctostaphylos* from 0.5% to 11%, *Artemisia* from 1% to 62% and *Ceanothus* from 11% to 20%. For all species (and fertilizers) survival of transplants in fall plantings was 26% and in spring plantings, 35%.

Where plants were lost due to fertilizer applications to improper placement of plant material or just to losses inherent in non-irrigated plantings, replacement plantings should be made to achieve the objective of complete revegetation. A revegetation program should certainly provide for such replacement, particularly when the plantings receive no care after planting.

However, a good "mix" of plant species has been established and, in time, these cuts should blend well with the surroundings.

Grass stands were sampled on all of the U.S.G.S. cooperative watersheds during the fourth week of July 1973 and again in June 1974. The number of grass seedlings were counted on square foot samples taken every three feet from the base to the top of the slope. The most obvious difference was in the amount of grass on the fall shrub seeded areas as compared to the spring shrub seeding. The spring shrub planting operation obviously destroyed much of the grass stand by trampling and burying the seed and seedlings of grasses. Counts averaged seven plants to the square foot on both counting dates on the areas where spring plantings of shrubs were made and 32 and 13, respectively, for 1973 and 1974 on the areas where shrubs were planted in the fall. All grass seeding was done in the

TABLE 9. Survival of Fall 1972 and Spring 1973 plantings at 7 sites on Highway 89 from peat pot liners and unrooted cuttings. Survival on June 4, 1974. Data given as: number surviving/number planted and summarized as totals of all subplots on each site.

	Fall 1972 Planting								
Site[1]	1	2	3	4	5	6	7	Total	Percent
Transplants:									
Arctostaphylos nevadensis	0/50	0/50	2/75	0/75	0/48	0/50	0/50	2/398	0.5
Artemisia tridentata	2/50	0/50	2/25	0/25	0/48	0/50	0/50	4/298	1
Castanopsis sempervirens						0/40	0/40	0/80	0
Ceanothus prostratus	1/40	0/50			17/80		0/40	18/170	11
Cornus stolonifera	0/40	0/60	0/25	0/25				0/150	0
Penstemon newberryi	9/160	53/160	120/160	86/160	274/400	131/200	96/200	769/1440	53
Purshia tridentata	0/100		0/50	0/50	0/100	0/100	0/100	0/500	0
Totals	12/440	53/370	124/335	86/335	291/676	131/440	96/440	793/3036	
Percent survival, all transplants	3	14	37	26	43	30	22	26	
Unrooted cuttings:									
Alnus tenuifolia		0/75						0/75	0
Ceanothus prostratus		0/30						0/30	0
Cornus stolonifera	0/100	0/225						0/325	0
Populus tremuloides		0/75						0/75	0
Salix lemmonii	142/300	315/600	154/400	117/200	130/200	150/400	137/400	1145/2500	46
Sambucus microbotrys		4/75	0/100	2/50	0/40	0/50	0/50	6/365	2
Spiraea densiflora		9/60				6/50	0/50	15/160	9
Totals	142/400	328/1140	154/500	119/250	130/240	156/500	137/500	1166/3530	
Percent survival, all cuttings	36	29	31	48	54	31	27	33	
Percent survival, Salix	47	53	39	59	65	38	34	46	

TABLE 9. (Concluded)

	Spring 1973 Planting*								
Site[1]	1	2	3	4	5	6	7	Total	Percent
Transplants:									
Arctostaphylos nevadensis	6/200	18/200	19/200	20/120	9/80	13/100	35/220	120/1120	11
Artemisia tridentata	166/280	175/280	224/280	151/200	24/80	47/100	192/380	984/1600	62
Ceanothus prostratus	33/600	69/600	200/800	198/600	35/200	78/500	162/600	775/3900	20
Penstemon newberryi	47/400	100/400	400/600	282/360	101/200	196/320	297/500	1423/2780	51
Purshia tridentata	71/280	85/280	126/280	71/200	4/80	8/100	23/300	388/1520	25
Sambucus microbotrys	14/40	13/40	14/40		16/40	20/40	11/30	88/230	38
Total	350/1822	460/1800	994/2225	739/1505	194/680	379/1187	726/2054	3842/11273	
Percent survival, all transplants	19	26	45	49	35	31	35	35	
Unrooted cuttings:									
Cornus stolonifera	2/25	7/300			1/40	2/90	4/60	16/515	3
Salix lemmonii	179/350	317/700	281/600	130/250	96/200	219/430	212/470	1434/3000	48
Total	181/375	324/1000	281/600	130/250	97/240	221/520	216/530	1450/3515	
Percent survival, all cuttings	48	32	47	52	40	42	41	41	
Percent survival, Salix	51	45	47	52	48	51	45	48	

*Total may be higher because some plants were still dormant and others buried.

[1]Sites:
1 = 03-ED-89 P.M. 2104-2.11
2 = 03-ED-89 P.M. 2.93-2.99
3 = 03-ED-89 P.M. 4.30-4.37
4 = 03-ED-89 P.M. 4.37-4.45
5 = 03-PLA-89 P.M. 1.13-1.18
6 = 03-PLA-89 P.M. 1.18-1.27
7 = 03-PLA-89 P.M. 1.27-1.42

fall of 1972, following the fall planting of shrubs. The larger number of seedlings is desirable for erosion protection in the first year, even though they do not all live.

However, the low plant count in areas planted with shrubs in the spring and the reduction in grass from 32 to 13 between July 1973 and June 1974 in the areas where shrubs were planted in the fall may be beneficial to shrub establishment by reducing competition. Because of extreme site to site microclimate variability, variations in the numbers and proportion of woody plant species used and varied subtreatments (fertilizers, time of planting, etc.) there was no evidence that short-term survival of woody plants was affected by herbaceous (grass) competition. Data collection 2-4 years following planting after fertilizer treatment effects are minimized will be required to determine such competition effects. To June 30, 1973, grass and woody species appeared to be growing in intimate association without severe competitive effects. However, much of the available literature indicates that heavy stands of herbaceous plants inhibits survival and growth of woody species.

Fertilizers

Determination of the fertility status of these mountain soils was done initially in greenhouse pot tests with both grasses and native woody species as indicator plants. Trials were then conducted on various sites to determine the plant responses under field conditions.

Pot tests with mountain soils from three sites, using oats as indicator plants showed (Table 10) large response to nitrogen and sulfur with lesser response to phosphorus for all three soils. Soils from the River Ranch (Lower Truckee River) location were also slightly deficient in potassium. No micronutrient deficiencies were indicated.

Another test was conducted to further define the nutrient status of the decomposed granite subsoils of the area using soil material from Kingsbury Grade and Bromus mollis (Blando brome) as an indicator plant. Treatments were a complete nutrient supply (N, P, K, S and zinc (Zn)), complete nutrients and Zn plus boron (B), copper (Cu), magnesium (Mg) and manganese,

TABLE 10. Relative yields* of oats grown on three Sierran soils and supplied with various fertilizers.

Treatment	Response Measured	Kingsbury Grade, Nevada	Gold Lake Road, California	River Ranch, California
Check	NPKS	4.2	7.5	4.0
PKS	N	7.3	10.3	5.1
NKS	P	54.2	29.7	46.8
NPK	S	29.4	38.1	26.4
NPS	K	109.0	93.9	79.4
NPKS		100.0	100.0	100.0
NPKS + micro-nutrients		102.0	84.8	100.0

$$\text{*Relative Yield} = \frac{\text{Yield of other trts}}{\text{Yield of NPKS trt}} \times 100$$

complete nutrients except for N, P, K, S and Zn (Zinc) and two commercial fertilizers, ammonium sulfate-phosphate (16-20-0) and magnesium ammonium phosphate (MagAmp, 8-40-0). The results (Table 11) again indicated a severe deficiency of N, P, S. There was no deficiency of zinc. Reduced yields with added manganese indicate that this element is high in this decomposed granite. The low yields from magnesium ammonium phosphate are probably due to the low solubility (and, hence, availability) of this nutrient source.

Several slow-release fertilizers were evaluated as nutrient sources and for rate of leaching in decomposed granite subsoils from Kingsbury Grade using _Bromus mollis_ (Blando brome) as an indicator. The cumulative yields from two harvests and the amount of nitrogen and phosphorus in 4 inches of leachate are given in Table 12. All fertilizers increased yields greatly with greatest yields from 16-20-0 (soluble; ammonium phosphate-sulfate) and the higher rates of resin-coated soluble fertilizers (Osmocote) and magnesium ammonium-magnesium potassium phosphate (MagAmp). Lowest levels of nitrogen and phosphorus in the leachate were in the 16-20-0 and sulfur-coated urea treatments. Large quantities of nitrogen leached from the resin-coated product and large quantities of phosphorus leached from the magnesium ammonium-magnesium potassium phosphate.

TABLE 11. Effect of nutrient application on _Bromus mollis_ (Blando brome) growth on decomposed granite subsoil from Kingsbury Grade.[1]

Treatment	Relative Yield %[2]
Full	100
+B	87
+Cu	104
+Mg	98
+Mn	64
-K	108
-N	6
-P	15
-S	12
-Zn	100
16-20-0	93
8-40-0	38

[1]Tests by the late W. E. Martin, Extension Specialist, Department of Soils and Plant Nutrition, University of California, Davis.

[2]LSD .05 (95% confidence) = 27
LSD .01 (99% confidence) = 36

TABLE 12. Evaluation of slow-release fertilizers in decomposed granite subsoil for growth response and resistance to leaching. Test plant, Bromus mollis, were grown for 54 days in subsoil from the Tahoe Basin. Cumulative plant yields after two harvests and nitrogen and phosphorus in 4 inches of leachate.

TREATMENT			RESULTS		
Fertilizer[1]	Rate,#/A		Yield,gm dry weight	Leachate, mg N/Pot	
	N	P_2O_5		N	P
Check	-	-	.02	1.12	.12
S-coated Urea	200	-	.08	1.67	.12
S-Urea + Rock PO_4	100	100	.42	1.74	.11
S-Urea + Rock PO_4	200	100	.65	3.02	.16
S-Urea + Super PO_4	100	100	.75	1.53	.20
S-Urea + Super PO_4	200	100	.99	2.32	.09
Osmocote 26-0-0 + Rock PO_4	100	100	.90	19.67	.11
Osmocote 26-0-0 + Rock PO_4	200	100	1.03	75.10	.09
Osmocote 26-0-0 + Super PO_4	100	100	1.07	10.92	.34
Osmocote 26-0-0 + Super PO_4	200	100	1.63	40.11	.13
Osmocote 18-6-12	100	33	1.19	37.79	.12
Osmocote 18-6-12	200	67	1.62	89.78	.10
MagAmp 7-40-6	100	571	.72	1.64	10.59
MagAmp 7-40-6	200	1142	1.31	1.68	34.04
NH_4 PO_4/SO_4 16-20-0	100	125	1.64	2.54	.26
NH_4 PO_4/SO_4 16-20-0	200	250	1.39	1.03	.29

[1] PO_4 = phosphate, S-urea = sulfur-coated urea, Osmocote = polymer-coated soluble fertilizers, MagAmp = co-precipitated, co-granulated magnesium ammonium-magnesium potassium phosphate.

Greenhouse tests using several of the woody species native to the Tahoe Basin had shown growth response to fertilizers. These results were reported in detail in progress reports for September-November 1971, and September-November 1972. Numerous field trials were established to test response of various species to several kinds of soluble and slow-release fertilizers.

Some of the possible benefits of fertilization are better transplant survival, increased growth during the first growing season, better winter survival, and, with controlled release fertilizers, increased growth during the second year. Controlled release fertilizers offer the potential of reduced salinity and pollution of drainage waters.

Several of the field tests were inconclusive either because of poor plant establishment or because of damage or destruction of the plots. For example, unrooted willow cuttings were planted in 1972 on a wet bank on the Ward Creek Road and fertilizer was placed in a separate hole approximately 1-2 inches from each cutting. Preliminary data indicated a substantial growth response to fertilizers. However, this planting was destroyed in mid-season by county highway crews. The results of trials from which valid conclusions may be drawn are discussed here.

Penstemon newberryi in 3 inch peat pots were planted in loose, moist sluff at the base of the cut at Kingswood Estates (03-PLA-267 P.M. 09.00) in May 1972. Approximately 1/2 the plants received no fertilizer and 1/2 received 20 gm (1.4 gm N) magnesium ammonium-magnesium potassium phosphate, 7-40-6 placed in the planting hole. The fertilized plants exhibited increased growth in both 1972 and 1973. By the spring of 1974 mean diameters were equal but there were obvious differences in size and density of plants. Several plants were harvested and fresh weights and number of stems per plant were determined (Table 13). Fertilized plants were 120% heavier and had 184% more stems than unfertilized plants.

TABLE 13. Effect of magnesium ammonium-magnesium potassium phosphate on growth of Penstemon newberryi. Kingswood Estates, 03-PLA-267 P.M. Planted May 23, 1972, data May 1974. Fertilized with 20 gm (1.4 gm N) 7-40-6 (MagAmp).

	Control	MagAmp
Diameter	38 cm	38 cm
Fresh weight	344 gm	413 gm
Number of stems	235	432

Fertilizer trials planted in May 1973 in Ward Valley and on Luther Pass (03-ED-89 P.M. 2.36) are reported in detail in Appendix IV. These trials evaluated the response of Penstemon newberryi and Cercocarpus montanus and Arctostaphylos nevadensis (on Luther Pass) to several slow-release and two soluble fertilizers. Results to late September 1973 are summarized in Appendix IV. Only two species, Penstemon newberryi and Artemisia tridentata responded to fertilization. Soluble fertilizers generally reduced survival greatly (Appendix IV, Table IV-2) except for Penstemon newberryi and Artemisia tridentata there were not appreciable differences in growth between fertilized and non-fertilized plants. The lack of growth differences may have been because water was the factor limiting growth.

Winter survival of plants in this experiment was very low. Data taken on May 29, 1974 are summarized in Table 14. Survival of Arctostaphylos nevadensis was so poor that these data are not included. Survival data for Cercocarpus montanus, Penstemon newberryi, Purshia tridentata and Artemisia tridentata are summarized in Table 14. There were no consistent patterns between fertilizer applications and winter survival (or mortality). Mortality may have been slightly increased by fertilization in all species except Cercocarpus but not markedly so. For all four species, loss of plants fertilized with controlled release fertilizers was 6.5% higher than the controls. Only two species, Penstemon newberryi and Artemisia tridentata had marked growth responses during the 1973 growing season. Of these two, only living and dead Artemisia could be measured accurately in June 1973. This species was measured and these measurements were evaluated against fertilizer treatments and survival. There was little or no correlation with fertilizer treatment but there was a strong inverse relationship between first year growth and survival. The data are presented (as histograms) in Fig. 4. It appears that gains in first year growth rate may be offset by increased winter losses.

Fertilizer studies were also carried out on a portion of spring 1973 plantings on the seven cuts on which integrated erosion control measures were installed. Two subplots were fertilized with soluble fertilizer (16-20-0), ammonium phosphate-sulfate, three subplots with Isobutylidine diurea (IBDU), six with magnesium ammonium-magnesium potassium phosphate (7-40-6, MagAmp), eight with urea-formaldehyde (UF) and 10 plots were used as controls. All fertilizers were applied in the planting hole at the rate of one gram of nitrogen per plant. The number of subplots within sites varied according to available space, uniformity of microsite and physical configuration of the plot. Because one goal of this study was adequate revegetation for erosion control, the number of replications were limited for the soluble fertilizer treatment and the relatively untested IBDU.

TABLE 14. Effect of soluble and controlled-release fertilizers on the first winter mortality of 4 species of woody plants native to the Tahoe Basin. All fertilizers applied at the rate of .5 gm N per plant at planting time, May 16, 1973. Fifty plants planted per treatment.

Species	Item	Treatment[1] C	MA	UF	SU	IBDU	AS	AS/P	TOTALS
Cercocarpus montanus	Survival 8/29/73	25	21	22	22	20	8	10	128
	Survival 5/30/74	6	8	5	7	5	3	4	38
	% Winter loss[2]	76	62	77	68	75	62	60	70
Penstemon newberryi	Survival 8/29/73	38	47	41	43	36	16	20	241
	Survival 5/30/74	13	7	8	9	16	3	4	60
	% Winter loss	66	85	80	79	56	81	80	75
Purshia tridentata	Survival 8/29/73	38	35	32	36	36	14	13	204
	Survival 5/30/74	30	21	24	26	23	10	9	143
	% Winter loss	21	40	25	28	26	29	31	30
Artemisia tridentata	Survival 8/29/73	50	47	43	48	50	43	28	309
	Survival 5/30/74	15	9	13	11	13	9	7	77
	% Winter loss	70	81	70	77	74	79	75	75
Totals	Survival 8/29/73	151	150	138	149	142	81	71	882
	Survival 5/30/74	64	45	50	53	57	25	24	318
	% Winter loss	58	70	64	64	60	69	66	64

[1]C = control; MA = co-precipitated, co-granulated magnesium ammonium-magnesium potassium phosphate, 7-40-6, coarse granual (MagAmp); UF = ureaformaldehyde; SU = sulfur-coated urea; IBDU = isobutylidine diurea; AS = ammonium sulfate, 21-0-; AS/P = ammonium phosphate-sulfate, 16-20-0; all at 1/2 gm N per plant.

[2]Percent winter loss = $100 - \frac{\text{Survival } 5/30/74}{\text{Survival } 9/29/73} \times 100$

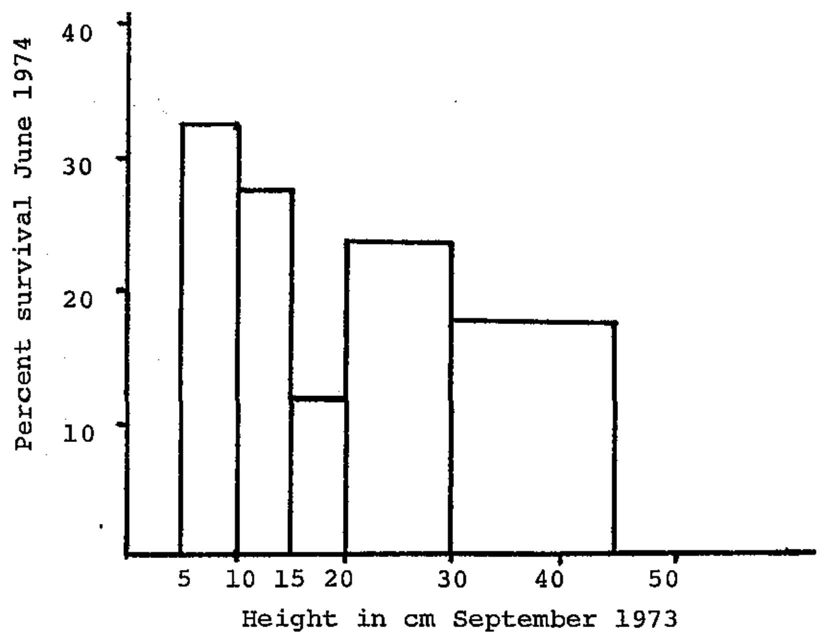


FIGURE 4 . Relation of first year growth to first winter survival for Artemisia tridentata planted May 1973 at approximately 7000' elevation on Luther Pass, 03-ED-89 P.M. 2.36.

TABLE 15. Effect of three slow-release fertilizers[2] and one soluble fertilizer on survival of five species of native shrubs on seven sites in the Tahoe Basin. Planted May 1973. Survival June 1974. Data given as number surviving/number planted and percent surviving.

Treatment[3]	Purshia	Artemisia	Arctostaphylos	Ceanothus	Penstemon	Total[1]
Control	177/480 37%	346/460 75%	43/290 15%	296/1210 24%	471/850 55%	1333/3290 41%a
UF	128/430 30%	290/430 67%	36/380 9%	262/1090 24%	433/790 55%	1149/3120 37%a,b
IBDU	22/200 11%	141/280 50%	25/150 17%	72/470 15%	187/380 49%	447/1480 30%b
MAP	61/370 16%	200/390 51%	16/260 6%	144/990 15%	315/760 41%	736/2770 27%b
16-20-0	0/40 0%	7/40 18%	0/40 0%	1/100 1%	27/100 27%	35/320 11%c
Total	388/1520 26%	984/1600 62%	120/1120 11%	775/3860 20%	1423/2880 49%	3690/10980 34%

[1]Duncan's Multiple Range Test: Treatments with same letter are not significantly different at the 99% level of confidence.
[2]Fertilizer rate was one gram of nitrogen per planting hole.
[3]UF = Urea-formaldehyde, IBDU = Isobutylidene diurea, MagAmp = Magnesium ammonium-magnesium potassium phosphate (MagAmp), 16-20-0 = Ammonium phosphate sulfate.

The survival data for species common to all treatments, taken in June 1974, are shown in Table 15. The soluble fertilizer (16-20-0) greatly reduced survival of all species. This reduction in survival, compared to all other treatments, was significant at the 99% confidence level. Survival (total of all species) was significantly less (99% level) for the IBDU and MagAmp treatments compared to the control treatment. Survival in these two treatments was reduced for most species compared to the urea-formaldehyde treatment but the differences were not statistically significant at the 99% confidence level. The degree of reduction in survival in the MagAmp treatment was unexpected, based on research reports by others. The least reduction in survival was with the urea-formaldehyde where three of the five species had reduced survival and two did not. In total, these reductions were not significant compared to the control. The control plots and all fertilizer plots received the broadcast application of 16-20-0 at time of seeding grasses (fall 1972) and two subsequent broadcast applications at 250 lbs/A.

Fertilization is recommended for Penstemon newberryi, particularly on moist sites. Without further studies, fertilization cannot be recommended for the other five species tested. Controlled release fertilizers are preferable to soluble ones to avoid salt injury. Greenhouse studies demonstrate that controlled release fertilizers are satisfactory for supplying Tahoe natives with nitrogen. Field studies do not indicate any consistent difference in growth response or survival between the controlled release fertilizers tested. Choice of a suitable controlled release fertilizer for use in the Tahoe Basin should be based on ease of measuring out an appropriate amount of fertilizer and the inclusion of supplemental amounts of sulfur and phosphorus within the fertilizer. While benefits of sulfur and phosphorus have not been shown under field conditions, greenhouse pot tests with a Tahoe soil and Penstemon as an indicator species indicate potential deficiencies of these nutrients. Of the controlled release fertilizers tested in these experiments, only urea formaldehyde, 20-10-5 (Agriform tablets), currently contains supplemental amounts of S and P. The convenience of using a premeasured tablet is obvious. An appropriate addition of fertilizer for Penstemon newberryi would be 1 to 2 grams of nitrogen or approximately 1 to 2 tablespoons of most controlled release fertilizers.

Many observations and experimental results in the course of these studies have demonstrated the necessity of using fertilizer for grass establishment.

In field trials, treatments using no fertilizer and those using a single minimal application (not re-applied as necessary) have resulted in stand failures of grasses by the end of the first growing season. Because of concern for effects of fertilizers on Lake Tahoe, minimum amounts of fertilizers have been used (250 lbs of 16-20-0 per acre) and these amounts have been observed to be insufficient by the end of the first growing season. A total of 250 lbs/A at the fall planting, plus 250 lbs/A in May, plus 250 lbs/A the second fall, appears adequate at Chamberland. It may or may not be necessary to fertilize again, but the plants should be watched for acute deficiency symptoms and enough fertilizer applied to keep the plants "green" as opposed to yellow when deficient or "dark green" when highly fertilized. Once the roots have developed to a great enough depth and nutrient recycling from decaying organic matter begins, grass may find the necessary nutrients without additional fertilization.

The use of a properly designed slow release fertilizer, either alone or in combination with conventional fertilizer, may reduce or eliminate the need for these reapplications. A test was established on Kingsbury Grade in April of 1972 to compare various fertilizer sources. The test was applied to a 2-year-old grass which had been fertilized for establishment purposes, but was acutely deficient. All treated plots still appeared to have adequate fertility in June 1974, while the check was surviving in a low vigor, poor ground cover and poor erosion control state. This study and others at 03-PLA-89 P.M. 1.18-1.27 and 03-ED-89 P.M. 2.11-4.45 should be monitored to determine the desirability of fertilizing to maintain adequate cover for erosion control.

RECOMMENDED SPECIES FOR EROSION CONTROL

Herbaceous Plants for Interim Stabilization

An initial comparison of herbaceous plants which might be used for erosion control purposes in the Tahoe Basin was made in the fall of 1970. Observations in the fourth growing season indicate there are many good perennial grasses (commercially available), but no legumes. The use of a rhizomatous grass is desirable because of its ability to spread and bind the soils. The first four grasses in Table 16 have rhizomes; western wheatgrass has the most rhizomes and has the shortest growth, while 'Oahe' intermediate produces much more top growth. Another wheatgrass, 'Luna' pubescent, is comparable to 'Oahe', but is not as commercially available.

Small seeded bunchgrass such as crested wheatgrass, Sherman big bluegrass, Durar hard fescue and orchardgrass are important because they give quick ground cover. They may later be replaced by the rhizomatous wheatgrasses. Potomac orchardgrass has been excellent for this purpose, is inexpensive, and available in quantity.

Cereals (wheat and rye) give some initial protection but have limitations. First, they may persist on the better growing sites and be very weedy. Second, they compete severely with the other species in the mix. Orchardgrass would be a better choice for quick cover.

Legumes are not able to survive well on these severe sites. Chesapeake red clover has done the best, but only on the best sites. Rambler alfalfa (rhizomatous) appears better than Ladak (tap rooted). Cicer milkvetch is still surviving at the best sites.

Woody Plants for Permanent Stabilization

The financial and time limit constraints of this project have forced us to set priorities on specific research efforts. Thus, our research has tended to focus on six native shrubby species because of their potential value for erosion control, ease of culture or initial success in establishment. Other species have not been investigated extensively because of initial problems in propagation or establishment, lack of suitable propagation material or because they have been judged of somewhat less potential value for erosion control. For example, a plant of sparse

TABLE 16. Herbaceous species adaptability for Interim Erosion Control in the Tahoe Basin. Ratings during the fourth growing season as 1 = none, 10 = excellent.

	SITE								
SPECIES	Tahoe Airport - flat fill	Tahoe Keys - flat fill	Kingsbury - non-fert. bench	Kingsbury - fertilized bench	Kingsbury - fill slope	Kingsbury - flat fill	Swiss Village - no fert. on soil	Ward Valley - cut slope	Mean
Western wheatgrass, Colorado grown	7	3	2	3	4	9	6	9	5
Sodar streambank wheatgrass	9	6	4	5	4	5	2	5	5
Topar pubescent wheatgrass	10	8	6	9	7	9	8	9	8
Oahe intermediate wheatgrass	10	9	5	10	6	8	8	10	8
Nordan crested wheatgrass	10	8	3	6	7	9	1	6	6
Durar hard fescue	10	6	4	7	5	10	7	7	7
Potomac orchardgrass	9	6	6	5	3	8	-	5	6
Sherman big bluegrass	6	8	8	10	6	10	10	10	8
Lincoln smooth brome	5	6	6	8	6	9	4	5	6
Nugains winter wheat	1	1	1	1	1	1	-	1	1
Tetra Pekus cereal rye	1	1	1	1	2	1	1	1	1
White clover	1	1	1	1	1	1	-	1	1
Alsike clover	4	2	1	1	1	1	-	1	2
Chesapeake red clover	4	2	2	1	1	1	-	1	2
Ladak alfalfa	2	3	-	-	-	-	-	-	3
Rambler alfalfa	3	5	-	-	-	-	-	-	4
Cicer milkvetch	4	2	-	-	-	-	-	-	3

habit would have a lower priority than a very dense plant, other factors being equal.

The six shrubs which have been studied most extensively are discussed briefly from the standpoint of erosion control, the research and present status of our knowledge.

<u>Arctostaphylos nevadensis</u> - Pine mat manzanita

Propagation techniques have been developed which result in 60-80% rooting from fall cuttings stuck in sweat boxes with bottom heat (see Appendix V). Pine mat manzanita is still difficult to handle in the nursery. It is very sensitive to salt build-up in the soil and probably to excess soil moisture. In addition to the difficulty in growing Arctostaphylos, the ability of this species to establish on cuts from transplants has been poor. Not only has the survival percentage been low, but growth has been minimal. After one and two seasons of growth it still has only one stem and is not much larger than the original transplant.

Artemisia tridentata - Sagebrush or Big basin sagebrush

Sagebrush is easy to propagate from seed. Well established plants in peat pots take only 2-3 months to grow. This species had an excellent survival percentage when planted on cuts. Of 1,600 peat pot transplants, 87% were alive after the first growing season. Growth rate was excellent. One-year-old plants that were dug up had roots extending more than two feet deep. The root system was not spreading but was more of a taproot, and plants were well anchored. Losses during the first winter were attributed in part to frost damage. Reduction in fertility and restriction of use to only the drier sites may reduce these losses by forcing plants in dormancy earlier in the fall.

Ceanothus prostratus - Squaw carpet

Propagation of this species is equally easy from seed and cuttings. Growth and survival in the nursery have been excellent. Establishment from peat pots and gallon cans has been poor in the Tahoe Basin. Of 3,900 peat pots transplanted in May 1973, only 775 survived the first winter, and of 80 gallons planted in October, 1972, only 17 remain alive. The reason for these low survival numbers is unknown. The plants were in excellent condition when planted, soil moisture was good and most of the cuts were stabilized prior to planting.

Squaw carpet is one of the most abundant ground covers in the Tahoe Basin and can be found growing naturally adjacent to many of our research plots. It appears to be slow growing for one or two years after transplanting, then relatively fast. The problem is keeping it alive during the first year. Since this plant is so abundant, easy to grow and an excellent erosion control plant, more work should be done to increase transplanting survival. Ceanothus species are nitrogen fixers and establishment problems may be associated with a lack of inoculation with the proper bacteria.

Penstemon newberryi - Newberryi penstemon (or Mountain pride)

Newberryi penstemon is easy to propagate (Appendix V) and grow in the nursery. Cuttings can be rooted and well established in peat pots in two or three months. The root system spreads laterally and stems root as they become buried. Among species tested Penstemon best survives complete burying. Survival was equally good from fall or spring plantings.

In most places, Penstemon were planted on the lower one-half of the slope, but where it was planted higher up (Luther #3 fall planting section B & C) the survival and growth have been excellent. It had, by far, the best survival of any species on the top one-third of these cuts. This is the most difficult portion to revegetate, grasses and the woody species, Arctostaphylos and Ceanothus, did poorly. Newberryi penstemon should be used more in these most difficult areas.

An average two-year-old plant at Kingswood Estates was 38 cm in diameter with some 430 short vertical shoots arising from the ground. In another planting at Bliss State Park, two-year-old plants had buried stems running two to three feet from the original planting stock.

Purshia tridentata - Antelope bitterbrush

Bitterbrush is easy to propagate from seed. Seeds planted directly in peat pots had over 75% germination and grew rapidly. Accumulation of salts three months after germination caused seedlings to lose vigor and eventually causes some dying. With adequate leaching or better quality (low in salts) water, this problem can probably be prevented. Unfortunately, the 1,500 transplants were damaged by salts and the initial survival was only 30%. The surviving plants over-wintered well and were vigorous growing plants the second year.

Salix lemmonii - Willow

Some 6,000 various sized, unrooted, dormant willow cuttings were planted on various dry and wet roadside cuts. Survival was equally good from fall and spring stuck cuttings. Of the three sizes of cuttings used, the 1/2 inch diameter cuttings rooted better than the smaller (1/4 inch) or larger (1 inch) cuttings. Cuttings pre-treated in 2000 ppm indolebutyric acid did not root any better than untreated cuttings. Cuttings soaked in water for 3 1/2 days did not root any better than unsoaked cuttings.

Although willows are usually found along streams or in wet areas, unrooted cuttings did amazingly well on very dry sites. Chamberland (03-PLA-89 P.M. 1.13-1.42) is such a site and nearly 50% of these unrooted willow cuttings survived. Because these unrooted cuttings are easily collected and require no time in rooting or nursery establishment, this is an inexpensive way to establish plants in the Tahoe Basin.

There are a number of other woody species which have various levels of potential. Until additional research is conducted on these, they might be used in a limited way in revegetation projects to add variety to the plantings.

Those to which some effort has been devoted include: *Nama lobbii*, *Prunus emarginata*, *Quercus vaccinifolia*, *Castanopsis sempervirens*, *Symphoricarpos acutus*, *Lonicera conjugalis*, *Ribes* spp., *Spiraea densiflora*, *Chrysothamnus nauseosus*, *Rhamnus rubra*, and *Populus tremuloides*. More research is needed on propagation, culture and establishment practices for these.

Species judged to have potential to which we have devoted little or no effort include: *Rosa woodsii* var. *ultramontana*, *Ceanothus velutinus*, *C. cordulatus*, *Arctostaphylos patula*, *Cercocarpus ledifolius* and *Rubus parviflorus*. We have only investigated one of the six willow species.

There are numerous herbaceous species with potential for erosion control. Because of constraints on this project we have not investigated some of these which may be very useful. Several species of *Lupinus* thrive under the harshest of conditions. Genera of *Compositae* abound in the Basin. Many were densely rhizomatous.

IMPLEMENTATION

It is proposed that implementation of these findings be encouraged in several ways. Some items in the appendix are proposed for separate publication in appropriate media. It is further proposed that one or more publications "package" the several aspects of this research in a users manual. This could be either a University or Caltrans publication (for the high mountain area) or a part of a statewide erosion control manual.

Some of these procedures, e.g. wattling and sticking willow cuttings, could be done by routine maintenance crews. These crews could also perform the mechanical stabilization procedures of breast-wall construction, slope rounding and scaling and let the planting to contract.

It should be stressed that the primary objectives of these plantings was erosion control. The planting plan is prepared for each site by first selecting a mix of species judged best suited to the site and then placing each species of the mix in those microsites on the cut (or fill) matching the requirements of that species. The planting plan should consider first of all the plant, the microsite and the microclimate. A valuable secondary objective was, of course, highway beautification. The very nature of the variable site conditions and the variability in survival will assure a natural looking planting that will blend with the surroundings.

Additional research, including administrative studies, to broaden the plant list and geographic areas of usefulness would aid implementation.

Feasibility

The cost-benefits of the revegetation of the cut slope on Luther Pass 03-ED-89 P.M. 2.4 are discussed in detail in Appendix II.

Estimates of the slope preparation and planting of the integrated watershed slopes, planted 1972-73, are summarized in Table 17. The slope preparation was performed by Ecology Corps crews. Willow wattling preparation and placement and fall planting was accomplished by these crews with assistance and direction by UCD personnel. Spring planting was accomplished by UCD personnel. A limited amount of equipment, front-end loaders and trucks were used.

The slope preparation and willow wattling work was inefficient because of the lack of training and motivation of these crews, interruption of work when crews were called for fire fighting duties and difficulty of coordinating hand work with equipment availability. Therefore, travel time is deducted from gross man hours and the time further adjusted for lack of efficiency by a factor of .75.

The total costs (rounded to whole dollars) are compared to 10-year maintenance costs for clean-up of erosion based on erosion data prepared by Howell (1) and a clean-up cost estimate of $9.00 per cubic yard.

The cost for revegetating Site 1 by using wattling instead of terracing would have been reduced. The serrations would not be recommended for this site in view of the accelerated erosion and poor revegetation which resulted from this treatment. Use of mechanized equipment for slope preparation or revegetation treatment of newly constructed cuts would materially reduce the cost estimates of Sites 2 and 3-4. Much of Sites 5-6-7 were in good condition because of recent sewer-line construction where slopes had been re-shaped, perhaps backfilled and the overhang eliminated. It was possible to use a high proportion of mechanization on that portion needing extensive work, hence, cost-benefit figures are very favorable.

TABLE 17. Estimated costs of site preparation and planting integrated watershed plantings in the Tahoe Basin.[1]

Item	Site[2] 1 Number	1 Dollars	2 Number	2 Dollars	3-4 Number	3-4 Dollars	5-6-7 Number	5-6-7 Dollars
Gross Labor, Fall, hrs.	1,258		1,046		1,012		588	
Travel Time, hrs.	186		189		192		149	
Net Labor, hrs.	1,072		857		820		439	
Labor, @ 75% efficiency, hrs.	804		643		615		329	
Spring Labor, hrs.	36		46		74		84	
Total Adjusted Labor[1], hrs.	840	8,173	689	6,704	689	6,704	413	4,018
Loader/Operator, hrs.	16.5	456	25	690	14	387	13	359
Truck/Operator, hrs.							15.5	328
Plants	2,197	769	2,800	980	4,580	1,603	5,211	1,824
Hydroseeding								
Total Dollars								
Lineal ft. slope	420		320		800		1,430	
Erosion cu. yd./yr.	32		20		36		79	
Annual Maintenance		288		180		324		711
Ten-year Maintenance		2,880		1,800		3,240		7,110
Net Cost, Pollution Control, Aesthetics[3]		6,518		6,571		5,454		(581)

[1]Cost basis: Labor @ $9.73/hr., Loader/operator @ $27.61/hr., Truck/operator @ $21.17/hr., Plants @ $0.35 each.

[2]Site: 1 = 03-ED-89 P.M. 2.04-2.11; 2 = 03-ED-89 P.M. 2.93-2.99; 3-4 = 03-ED-89 P.M. 4.30-4.45; 5-6-7 = 03-PLA-89 P.M. 1.13-1.42.

[3]( ) = gain on 10-year amoratization. A 20-year amoratization would decrease pollution control and aesthetic benefit costs of Site 1 to $3,638, Site 2 to $4,771, Sites 3-4 to $2,214 and Sites 5-6-7 to a gain of $7,691.

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2. Kraebel, Charles J. 1936. Erosion Control on Mountain Roads. Circular No. 380. United States Department of Agriculture. Washington, D. C.

3. Quint, Mike. 1973. Contour Wattling & Willow Planting Work on Slope 03-ED-89 P.M. 2.4, Env. Imp. Sec. Caltrans - memo to file.

APPENDIX I

Mechanical-vegetation Stabilization for Slopes 3/4:1 or Steeper: Breast Walls and Brush Layering

Andrew T. Leiser

A combination of dry-laid rock rubble walls (breast walls) and vegetation can be used to stabilize very steep slopes or to stabilize areas subject to river or stream action.

Breast walls differ from retaining walls in that, being placed against relatively undisturbed earth, they receive little force from the material behind them. Schematic diagrams of breast wall construction are shown in Fig. I-1. A brief synopsis of construction which might serve as a basis for specifications follows.

1. Rock should be as large as possible, consistent with the height of the wall and shall be laid in a stable manner, e.g. the center of gravity should be below the midpoint of the rock.

2. Bedding of the rock shall be toward the slope and batter of the wall shall be at least 1 in 8.

3. The base of the wall shall be 1/2 the height and shall be placed on undisturbed soil or rock sloping into the bank.

4. Any backfill shall be tamped firmly in place as construction progresses.

5. Green willow branches shall be laid in the interstices of the wall, extending back into the backfill and shall be covered so that no air spaces are around them.

6. Smaller rocks may be used in the interstices of the wall to reduce the amount of exposed soil. These must be placed so that they are firmly held.

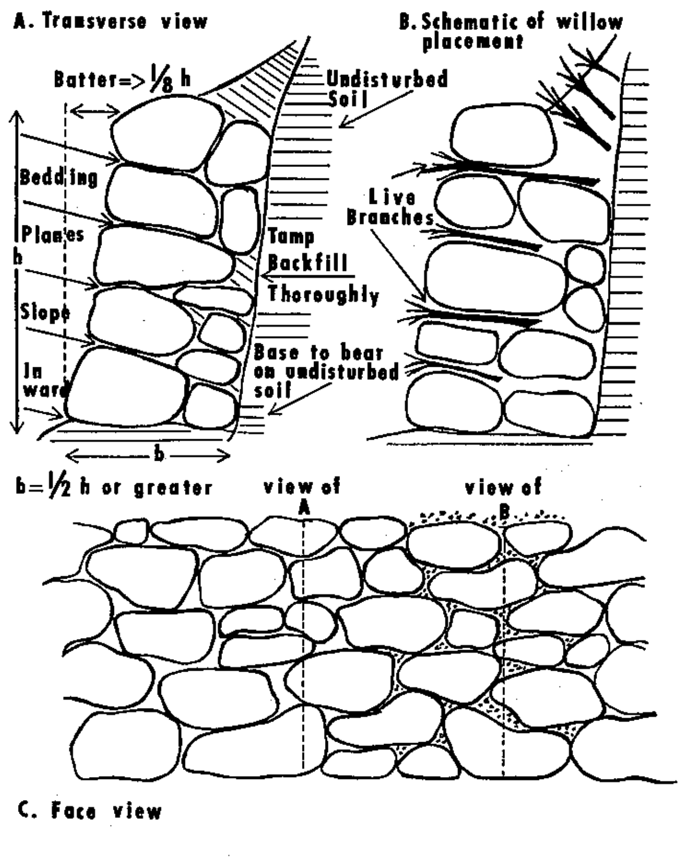
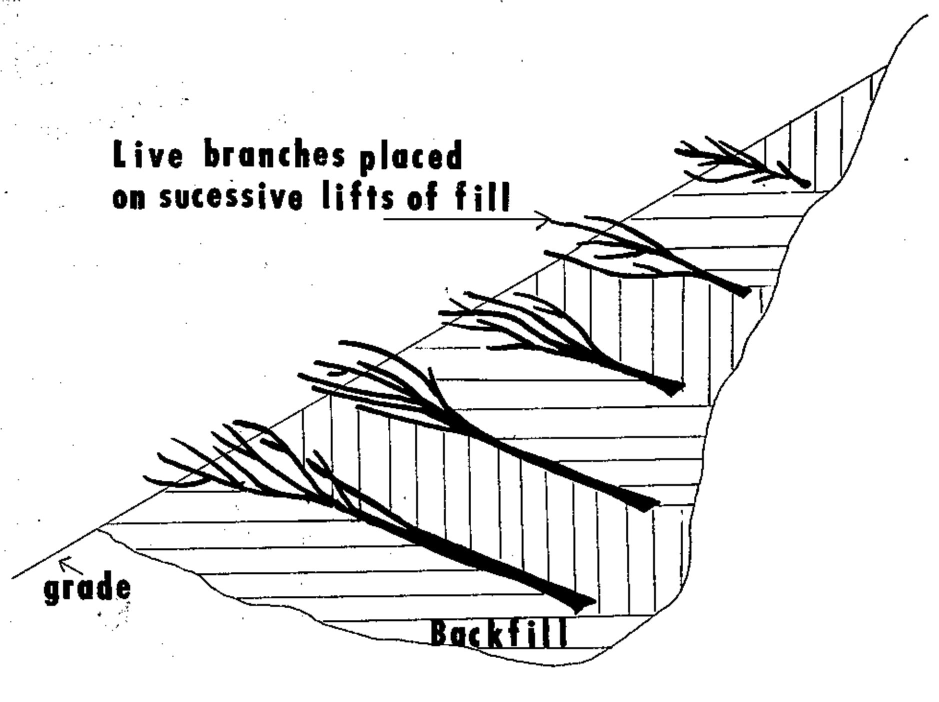


FIGURE I-1. Rock rubble breast walls-vegetation stabilization. A. and C: Construction detail showing bedding of rock on rock and general slope of stone into bank. B. and C: Schematic detail of willow placement.

The use of woody plant material (brush) can aid in the stabilization of fill areas. Species with flexible stems and which are capable of taking root are preferred because the resulting root systems and top growth give more or less permanent protection to the areas. If such species are not available, species which do not root will supply interim stabilization until other vegetation can be established. The application of plant material has been termed "brush laying" in Europe and the name rather simply indicates the technique. It is applicable to either small or very large areas of fill. The process consists of placement of layers of 3-4 ft. long brush alternately with the lifts of fill as the work progresses. The method is illustrated in Fig. I-2 as it might be installed over an eroded area. On larger fills, the brush placement might be increased to layers between 3-4 ft. lifts of fill and the length of brush might also be increased. The brush should be placed more or less randomly with some criss-crossing of stems for most effective stabilization. The layers of brush should be laid horizontally to avoid channeling water at any point.

Brush layering may be used during original construction or as a remedial action for seriously erroding areas. Properly installed it can be an effective, relatively economical solution to a variety of erosion problems.

FIGURE I-2. Backfill detail for erroded area of slopes greater than 3:1. Backfill tamped in lifts approximately 1 ft. thick, sloping into hillside. Green Salix (willow) branches layered between lifts. Branches 3/4 - 2 in. dia. spaced 8-12 in. o.c. maximum.



APPENDIX II

Time Study Analysis of Contour Wattling and Willow Planting Work on Luther Pass, Cut Slope at 03-ED-89, P.M. 2.4[1]

Edited By
Andrew T. Leiser

A large cut on Luther Pass, 03-ED-89, P.M. 2.36-2.52 had remained essentially unvegetated since construction until 1973. This cut was estimated (1) to produce 108 cubic yards erosion per year and accounted for 36% of the estimated highway erosion in the Grass Lake Creek Watershed although it is only about 12% of the highway cut and fill slope frontage. A stabilization-revegetation work plan was developed by Environmental Improvement Section personnel and University of California, Davis revegetation project principal investigator to use 35 man days of available labor. The work plan was to place 3 1/2 rows of wattling on 20 foot centers across the slope with additional rows in two severely gullied areas and to plant approximately 12,000 unrooted willow cuttings on approximately 18 inch centers. The number of cuttings was subsequently reduced to about 8,000 placed on 2 foot centers.

The project, as completed, is shown diagramatically in Figure II-1. A photograph of the cut before treatment is shown in the main body of the report, Figure 3. After installation of the wattling and planting of the cuttings, the slope was hydroseeded with a grass mixture consisting of:

Sherman big bluegrass 3#/A

Potomac orchardgrass 13#/A

Topar pubescent wheatgrass 21#/A

Oahe intermediate wheatgrass 20#/A

Magnesium ammonium/potassium phosphate (MagAmp) fertilizer was applied at 500#/A. The left (west) portion of the slope had wood fiber (Silva-fiber) at 3,000#/A and the right (east) had modified reclaimed paper (Tinex) at 2,880#/A added to the hydroseeding slurry.

On May 21, 1973, the wattling and willow planting work commenced with the cutting of willow branches from a meadow right of ED-89 P.M. 4.35 and the preparation of wattling bundles and willow cuttings. The basic work crew consisted of seven men.

Some of the willows were in areas under 6 inches of water. Thus, the cut willow branches had to be hand carried (up to a few hundred feet) to a dry area where the bundling and preparation of cuttings could be performed.

It was decided that the wattling and willow planting operation would be concentrated on the right portion of the slope and the main gullies, as it appeared that by projecting Monday's rather low production rates, it would not be possible to complete the work as originally planned. However, by late afternoon on Tuesday, May 22 it was found that the production rate had increased substantially and it was decided to proceed on the basis of placing wattling and willow cuttings on the entire slope.

Placement of the wattling on the slope was started in the afternoon. It was decided to modify the operation by using 2 x 4 x 24" construction (con) stakes to attach and anchor the wattling to the slope, instead of willow stakes. The con stakes were much easier to handle and drive into the slope and appeared to provide better anchoring for the wattling.

It started raining at about 1400 hours and work was suspended.

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[1]Abstracted from: Quint, Mike; May 30, 1973; Contour Wattling and Willow Plant Work on Slope at 03-ED-89, P.M. 2.4; "Memo to File", Environmental Improvement Section, Transportation Laboratory, California Transportation with additions and summary by A. T. Leiser.

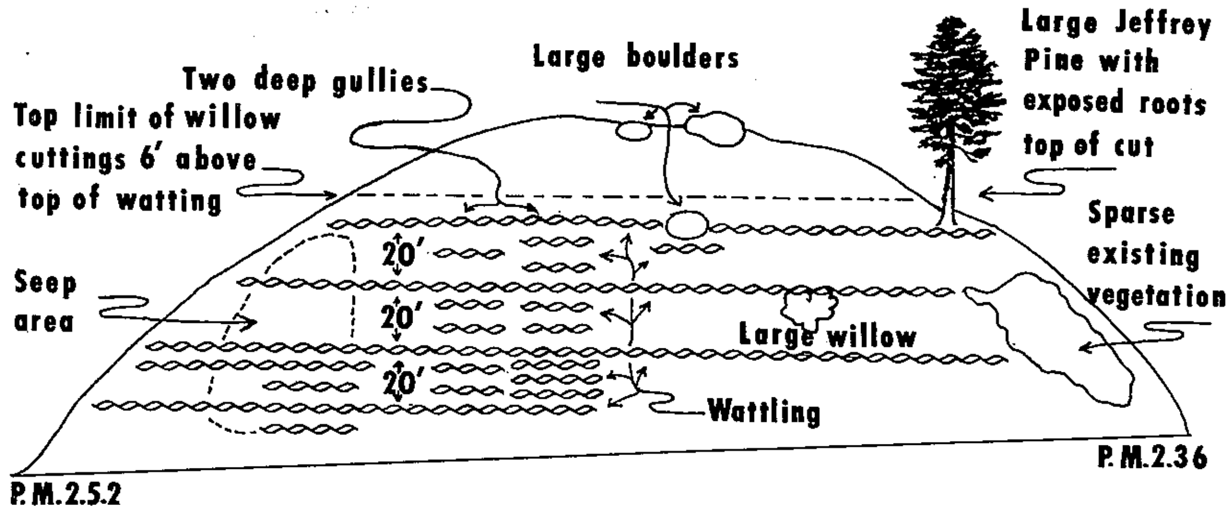

FIGURE II-1. Cut slope face at Luther Pass, 03-ED-89 P.M. 2.4 (P.M. 2.36-2.52) showing major features and wattling placement. NOT TO SCALE. Slope approximately 840 ft. long, 120 ft. high.

On May 23 the preparation of the wattling was completed in the morning while the preparation of the willow cuttings and the placement of the wattling on the slope continued throughout the day.

A time-study was conducted of the wattling cutting, bundling and tying operation for one hour on Wednesday, May 23. A four-man crew was utilized with one man cutting willow brush with a chain saw, one man removing brush as it was cut and two men stacking and tying. The chain saw was operated 40 minutes and 10 minutes was spent adjusting chain tension. During 50 minutes, 26 bundles, 8-10 feet long were stacked and tied. The remaining 10 minutes was calculated as a portion of "break" time and time to move from clump to clump as would be required in a sustained operation. On this basis, a four-man crew should be able to cut, sort, stack and tie 200-210 bundles a day. With mean length of 9 feet, production would be 1800-1890 lineal feet of wattling per crew day or 450-475 lineal feet per man day. Mechanization of the tying operation, e.g. use of a banding machine, might increase output further.

Wattling preparation and placement are discussed in detail in Appendix III.

Planting of the willow cuttings on the slope was started in mid-afternoon.

It was noted that in overlapping the wattling bundles (±1' overlap) on the slope, care should be taken in placing stakes within the overlap area as this is the weakest point in the wattling. This should include one diagonal stake within the overlap area and vertical stakes on each side of the overlap area on the downslope side of the wattling.

On May 24, the work was hindered throughout the day by light intermittent rain. Placement of the wattling was completed in the morning while the willow planting operation continued throughout the day.

It was noted that it was rather difficult to drill holes and plant willow cuttings in the areas where the wattling was spaced in 20' rows. Workers had a tendency to slide down the slope, and walking along the slope would loosen the earth and push it down to the wattling row below. If the wattling rows were spaced at a maximum of about 6' one could use each wattling row as a bench while planting the willows in the slope area above.

It was noted that some of the workers were planting the willow cuttings improperly. On some areas of the slope (upper right area) the rows of willows were planted in columns instead of staggering each row. Planting should be staggered on each row to control future runoff water and erosion.

o o o o o o	o o o o o o
o o o o o o	o o o o o
o o o o o o	o o o o o o
o o o o o o	o o o o o
o o o o o o	o o o o o o
<u>Wrong Way</u>	<u>Right Way</u>

The willow planting was completed at 1300 hours on May 25. A total of 8,000 willow cuttings were planted and a total of about 1140 lf, net, of wattling were installed on the slope during the week.

Willows were placed at an average of about two foot centers. The left lower portion (about 50' or so) of the slope below the bottom row of wattling was planted at about three foot centers as there was a shortage of cuttings.

The supply of auxin solution was exhausted during the morning. Willows planted on the left lower portion of the slope were not treated with the solution.

Underground water seepage and slumping was observed at the left end (50' or so) of the slope. Water seepage undercut one area below a row of wattling and created a small gully. It appears that there is a surface layer of loose sandy soil resting upon a compact and cemented lower layer in this area of the slope. As the surface layer becomes saturated with underground water seepage, the combined weight of the surface soil and water causes the surface soil to slump. A small amount of additional wattling was installed in this area. If the slumping action continues more wattling should be installed and if this does not control the erosion, horizontal drains may need to be installed to intercept the seepage.

A labor and cost summary was prepared for the work performed during the week. The itemized summaries are presented here. The costs were about $2./lf for the wattling and about 23¢/ea. for the willow plantings. However, it must be noted that these figures are based on a one week operation performed by a rather inexperienced crew under inclement weather conditions and without mechanized equipment. An analysis of the wattling and willow cuttings operation with production and cost projections is presented later.

<u>Labor Summary</u>

		Man Hours
1.	Scaling	4
2.	Cutting Willow Branches	36
3.	Preparing Wattling	28
4.	Preparing Willow Cuttings	34
5.	Layout (for Wattling)	9
6.	Install Wattling	75
7.	Plant Willow Cuttings	76
8.	Down Time (due to rain)	20
9.	Travel Time	84
	Total	366

<u>Production Summary</u>

A basic 7 Man Crew Working for 1, 40 hour, Week:

1. Prepared and installed about <u>1,140 lf of wattling</u> (127 bundles at about 9 lf per bundle);

2. Prepared and planted about <u>8,000 willow cuttings</u>.

Cost Summary

1. Prepared and Install Wattling (1,140 lf)

   a. Labor

	Man Hours
1) Scaling (1/2 total)	2
2) Cutting	27
3) Prepare (stack, tie, load)	28
4) Layout	9
5) Install	75
6) Down time (rain, 1/2 total)	10
7) Travel (from Sacramento, Marysville, 1/2 total)	42
	193 @ $9.00* = $1,737

   b. Material

1) 840 Con Stakes (2x4x24") @ 25¢ ea.	$210
2) Misc. (twine, gas, etc.)	50
3) Willows (obtained from Forest Service)	0

   c. Equipment

1) Chain saw	25
2) Transportation and trucking	200
3) Misc. (shears, mattock, shovel, hammer, etc.)	25
Total	$2,247

   Unit Cost: $2,247 ÷ 1,140 = $1.97/lf, say $2.00/lf for Wattling.

2. Prepare and Plant Willow Cuttings (8,000 Cuttings)

   a. Labor

	Man Hours
1) Scaling (1/2 total)	2
2) Cutting	9
3) Prepare	34
4) Plant	76
5) Down time (rain, 1/2 total)	10
6) Travel (from Sacramento, Marysville, 1/2 total)	42
	173 @ $9.00* = $1,557

   b. Material

1) Willows (obtained from Forest Service)	$ 0
2) Misc. (twine, auxin solution, etc.)	50

   c. Equipment

1) Transportation and trucking	200
2) Misc. (shears, drills, hammers, etc.)	25
Total	$1,832

   Unit Cost: $1,832 ÷ 8,000 = $0.229¢/ea., say 23¢/ea. for Willow Cuttings

   <u>Or</u>

   6¢/sq. f. (based on planting willows at about 2' centers).

*$7.00/hr. + $2.00/hr. subsistence.

Cost Summary (Conclusion)

It should be noted that these costs includes slope scaling, down time due to rain and crew travel time and mileage between Sacramento or Marysville and the job site at Luther Pass.

First year results of this project are discussed in the body of the report, p. 6. Rainfall data for 1973 collected on this site are given in Table 2 of the report.

Analysis and Projections

It is interesting to note that the contour wattling and planting techniques were used on fill slopes in Southern California in the early 1930's. An excellent detailed description of these procedures on fill slopes has been published (2).

The contour wattling process appears to offer a sound method of controlling surface erosion on highway cuts as well as fill slopes by mechanically anchoring the slope surface to the firm underlying soil. Wattling performs three basic functions.

1. Stabilizes the upper layer of soil to a depth of 6 to 10 inches against downhill surface movements.
2. Intercepts and forms barriers against the downward gullying of the slope during heavy rains.
3. Allows the start of vegetation on the slope by keeping the surface soil from moving.

Some possible modifications to the wattling and willow planting operation, with production and cost projections (envisioning an efficient production operation) are:

1. Power cutting (e.g. chain saw) of the willow branches, and power bundling of the wattling (e.g. nursery bundle tyers or banding machine): It is projected that an efficient four man crew (one man on chain saw, one man pulling out branches, two men bundling or feeding the power bundles) should be able to cut and prepare about 25-30 bundles (250 to 275 lf of wattling per hour or 15 to 20¢/lf. Also, it is projected that an efficient 6 man crew should be able to install about 150 to 200 lf of wattling per hour or 30-40¢/lf. Costs of construction stakes, twine, chain saw, trucking, etc. at about 45¢/lf. would make the cost of wattling installation 90¢ to $1.05 exclusive of scaling or other site preparation. A power trencher capable of working on steep slopes and pneumatic hammers for driving stakes and tamping soil over the wattling might materially reduce labor costs.
2. Power cutting of willow brush (e.g. chain saw) and power cutting of willow cuttings (e.g. band or circular saw): Production of willow cuttings with hand cutting of brush and individual cuttings required 34 man hours for 8,000 cuttings (p. 30,31) or 4.25 man hours/1,000. Using the increased production rate for wattling preparation actually found in the one hour time study (without mechanical tying) of 280%, a production rate of 1.5-1.6 man hours per 1,000 cuttings might be anticipated. At $9.00/hr., cost would be <2¢ per cutting. Hand planting costs at 50 to 200 cuttings per man hour would be 4 to 18¢ per cutting for a total unit cost of 6-20¢ per cutting. Again, this estimate does not include slope preparation, travel time or time lost due to weather. Mechanization of planting by use of pneumatic drills should decrease costs further.

In summary, it appears that the contour wattling technique can offer an effective and feasible means of controlling surface erosion pending the establishment of vegetation. Further research along these lines could lead to the development of more economical alternatives or substitutes, and to the formation of definitive guidelines for construction and maintenance work forces. One of the major questions remaining to be answered in this process is the most effective spacing of the rows of wattling on cut slopes.

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APPENDIX III

Wattling as an Erosion Control Method

Andrew T. Leiser

A title "Wattling Revisited" would perhaps be even more appropriate, for this is an old technique, tried and true, which has been largely neglected in the United States in the past quarter century so far as we can determine. We stumbled upon it, somewhat by accident, tried it in a new way and modified some techniques for making and installing it, but credit should be given to others for developing the technique of wattling.

A publication of the Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service, by Kraebel (2), was published nearly 40 years ago describing the use of wattling to control erosion on highway fill slopes in Southern California and in the Berkeley area. This information was included in later publications by Kraebel and Horton, Horton, and in a joint publication of the California Division of Highways, California Division of Forestry and the U. S. Forest Service. The technique may be currently in use in Europe.

Webster's Collegiate Dictionary defines Wattle as follows: n. (AS, watel, watul, watol, interwoven twigs) 1. A twig or flexible rod; a withe; wand; hence, a framework or hurdle made of such rods. 2. pl. Rods tied on a roof to support thatch. 3. Material consisting of wattled twigs, withes, etc., used for walls, fences, etc. (In Australia - Acacia -- from hurdles made by settlers of the branches.) The word may also be used as an adjective or a verb. The use of the word here is slightly different from the definition of Webster's Dictionary in that the bundles of flexible twigs are not interwoven but are merely tied in bundles. These bundles are then laid in trenches cut on contour on cuts or fills. The bundles are staked down to hold them firmly in place and are partially covered with soil. These rows of wattling then act as sediment traps for materials moving down the slope, for energy dissipators for soil and water movement and effectively reduce the slope angle of a small area immediately above each row. This area between wattling rows is an excellent site to establish other plant material. If the wattling is made of a species which roots easily, such as willows, the rows of wattling become a part of the semi-permanent or permanent stabilization system.

Research Results

Analyses of the causes of the heavy losses suffered in early stages of our Tahoe Revegetation Project convinced us that a primary factor was slope instability.

Field conferences with Caltrans personnel in 1972 developed several concepts for interim highway cut stabilization in the Tahoe Basin research area. These were: serrated cuts for a highly cemented soil; rock breast-walls, top slope rounding, wattling in the backfill areas; and backfill and wattling for others. The wattling was used in fills or soft areas of cuts. Woody plant transplants and grass seeding was used on all sites.

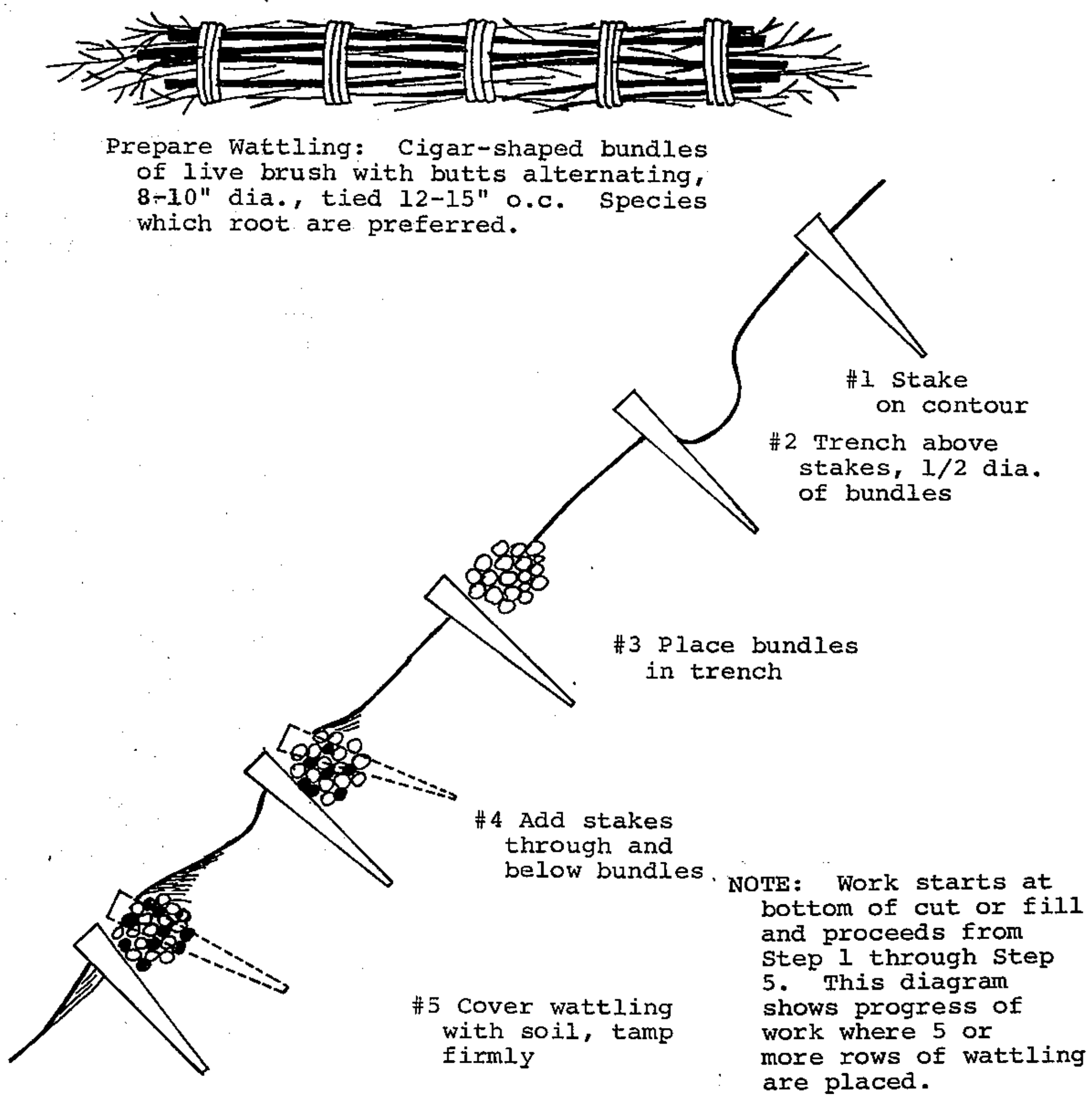
The serrated cut disintegrated during spring thaws, burying or carrying much of the plant material into the gutter. The breast-walls all held and the soft areas, with wattling, remained firmly in place, even though they had been freshly filled in the fall. The results with wattling were so spectacular by the spring of 1973 that District 03 and Translab Environmental Section personnel laid wattling in May 1973 on a cut 120 ft. high by 400 to 500 ft. long (approx. 1 acre). The project is described in detail in Appendix II. This cut, located in the Grass Lake Creek Watershed between ED 89 PM 2.36 and 2.52, was listed as the worst single cut on California State Highways in the Tahoe Basin for erosion. This erosion amounted to about 108 cubic yards per year (1). Wattling was spaced at 20 ft. intervals instead of the recommended three to four ft. The wattling was combined with sticking of willow cuttings approximately two ft. o.c. and overseeding with a perennial grass mixture. In a single season, the erosion was essentially stopped and the slope was stabilized.

Results with wattling used on cuts have been so consistent and effective that we feel the use of wattling should be extended to "undisturbed" cuts as well as to disturbed cuts and fills. No mulches (excelsior, fiber, jute), plastic or organic sprays or woodfiber treatments alone have given such satisfactory and consistent results.

Wattling Application

Preparation and placement of wattling can perhaps be best described by use of an illustration and a sample set of specifications. Figure III-1 is a composite diagram of a bundle of wattling and the various steps in the proper placement of the wattling. These steps are shown as a progression and might well illustrate the various stages underway on a large wattling project. The installation should start at the bottom of either a cut or fill and progress toward the top. A sample set of specifications follows:

FIGURE III-1. Wattling Installation - schematic diagram.



1. Wattling bundles shall be prepared from live, shrubby material, preferably of species which will root, such as <u>Salix</u> spp. (willow), <u>Baccharis</u> spp. (Coyote bush and Mulefat), etc.

2. Wattling bundles may vary in length, depending on material available. Bundles shall taper at the ends and shall be 1 - 1 1/2 ft. (max. 2 ft.) longer than the average length of stems to achieve this taper. Butts shall not be more than ±1 1/2 in. in diameter.

3. Stems shall be placed alternately (randomly) in each bundle so that approximately one-half the butt ends are at each end of the bundle.

4. When compressed firmly and tied, each bundle shall be ±8 in. in diameter (±2 in.).

5. Bundles shall be tied on not more than 15 in. centers with two wraps of binder twine or heavier tying material with a non-slipping knot.

6. Bundles shall be prepared not more than two days in advance of placement except that if kept covered and wet they may be prepared up to seven days in advance of placement.

7. Grade for the wattling trenches shall be staked with an Abney level, or similar device, and shall follow slope contours (horizontal).

8. Trenches shall be 3 ft. vertical spacing (or such other spacing specified. Economics may dictate wider placement).

9. Bundles shall be laid in trenches dug to approximately one-half the diameter of the bundles, with ends of bundles overlapping at least 12 in. The overlap shall be as long as necessary to permit staking as specified below.

10. Bundles shall be staked firmly in place with vertical stakes on the down-hill side of the wattling not more than 18 in. on center and diagonal stakes through the bundles on not more than 30 in. centers (see Fig. III-1). Where bundle overlap occurs between previously set bottom or guide stakes, an additional bottom stake shall be used at the midpoint of the overlap. Bundle overlaps shall be "tied" with a diagonal stake through the ends of both bundles.

11. Stakes may be made of live wattling material greater than 1 1/2 in. in diameter or they may be construction stakes (2" x 4" x 24" or 2" x 4" x 36", diagonal cut). Reinforcing bar may be substituted only as specified below.

12. All stakes shall be driven to a firm hold and a minimum of 18 in. deep. Where soils are soft and 24 in. stakes are not solid (i.e. if they can be moved by hand), 36 in. stakes shall be used. Where soils are so compacted that 24 in. stakes cannot be driven 18 in. deep, 3/8 - 1/2 in. steel reinforcing bar shall be used for staking.

13. Work shall progress from the bottom of the cut or fill toward the top and each row shall be covered with soil and packed firmly behind and on the uphill side of the wattling by tamping or by walking on the wattling as the work progresses or by a combination of these methods.

14. The downhill "lip" of the wattling bundle shall be left exposed when staking and covering are completed. However, the preceding specification must be rigorously adhered to.

Feasibility of Wattling

A natural question arises as to the economic feasibility of wattling as an erosion control measure. There are no recent large scale contract wattling installations on which to base exact answers. Kraebel (2) indicated a production of wattling at the rate of 40 bundles per man per day. This figure was based on the use of hand pruning saws to cut the plant material. Cost estimates based on the use of chain saws for cutting brush and other suggestions for mechanization preparation and placement of wattling and unrooted cuttings are discussed in detail in Appendix II. On a cost-benefit comparison with the cost of erosion clean-up, over a several year period, wattling installation is feasible. When one considers the intangibles of reduced erosions effect on the quality of the environment and the reduction in risk from debris on the highway and rolling rocks, it would seem that we cannot afford not to use wattling where it will stabilize cuts and fills.

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1. Howell, Richard. 1971. Slope Erosion Transect Lake Tahoe Basin, Interim Report. Materials and Research Department Research Report No. M&R 657078-1. State of California Department of Public Works, Division of Highways.

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APPENDIX IV

Growth Response of Highway Plantings to Controlled Release Fertilizers

W. H. Thornhill, J. L. Paul and A. T. Leiser

Introduction:

Highway construction in mountainous areas often exposes steep and erosive subsoils. These sites should be revegetated, but establishing plantings is sometimes extremely difficult. Such slopes are often bare of vegetation for 10 or more years after construction. It has been suggested that one reason revegetation is slow might be the extremely low nutrient content of these subsoils.

Pot tests with Purshia tridentata using subsoil from a shallow granitic soil in southern Idaho (3) indicated a fourfold increase in weight over that of control plants with soluble nitrogen fertilization.

Of particular concern in alpine regions is the eutrophication of lakes and streams, therefore, controlled release fertilizers may be more desirable than soluble forms. Several studies have been conducted with woody plants showing growth responses to the application of controlled release fertilizers such as ureaformaldehyde, resin coated soluble fertilizers, sulfur-coated urea and co-precipitated, co-granulated magnesium ammonium-magnesium potassium phosphate, (1, 2, 4, 6). In addition, a recent product from Japan, isobutylidine diurea (5), has been suggested as a slow-release nitrogen source.

These experiments were conducted to determine response of five selected native species of the Tahoe Basin to the application fertilizers. Plantings were made on the Ward Valley road (Site #1) and Luther Pass highway, 03-ED-89, Post Mile 2.36 (Site #2). Both sites were south facing highway cuts which had remained bare of natural cover for at least five years. Soil at Site #1 was a mixed sediment deposit and at Site #2 it was decomposed granite. Both sites were about 7000 feet elevation. Greenhouse pot tests on these soils indicated extreme nitrogen and moderate phosphorus and sulfur deficiencies using Penstemon newberryi as indicator plants.

Experimental Design

The field plantings consisted of the following treatments: control (no fertilizer), two soluble fertilizers, ammonium sulfate and ammonium sulfate/phosphate, and four controlled release fertilizers, magnesium ammonium/potassium phosphate (MagAmp), ureaformaldehyde (UF), sulfur coated urea and isobutylidiene diurea (IBDU), at a rate of 1/2 gram nitrogen per plant (see Table IV-1). Additional sulfur and phosphorus were added, as needed, to the controlled release fertilizers to supply adequate amounts of these nutrients. Ammonium sulfate, alone, was applied as a treatment to evaluate response to phosphorus. The species tested on Site #1 (Ward Valley) were Penstemon newberryi and Cercocarpus montanus. Artemisia tridentata, Purshia tridentata, and Arctostaphylos nevadensis were planted on Luther Pass at Site #2. All were transplanted from 2 1/4" peat pots. The Penstemon and Arctostaphylos were grown from cuttings and the others from seed. There were five replications each with 10 plants, per treatment.

The planting technique consisted of placing a measured amount of fertilizer in the bottom of the planting hole and placing the rootball on top of the fertilizer. Fertilizer rate was 10 lbs. N/Acre at the spacing used.

The plots were planted on May 16, 1973 and observations were made periodically during the summer, with final data taken September 29, 1973.

Results

Survival percentages for the five species are given in Table IV-2. Mean survival, pooling all species, was not reduced by any of the controlled-release fertilizers although for certain species, there may have been a trend for reduced survival. None of the reductions in survival were statistically significant at the 95% confidence level. There was a

TABLE IV-1. Types and amounts of fertilizers used in field plantings of five species of Tahoe Basin natives.

Symbol*	Fertilizers**	Supplementary S and P/plant
C	Control	None
MA	MagAmp (7-40-6)	1/2 tsp. (teaspoon) Ag. gypsum (S only)
UF	Urea formaldehyde (38-0-0)	1/2 tsp. single super phosphate (S & P)
IB	IBDU (31-0-0)	1/2 tsp. single super phosphate (S & P)
SU	S-coated urea (36-0-0)	1/2 tsp. single super phosphate (S & P)
AS	Ammonium sulfate (21-0-0)	None
AS/P	Ammonium sulfate/ phosphate (16-20-0)	None

*Symbols used in Figs. 1 and 2.

**Rate of application = 1/2 gm N/plant.

TABLE IV-2. Effect of several slow-release and soluble fertilizers on survival of five species of woody plants native to the Tahoe Basin. Planting date May 16, 1973, survival on September 29, 1973.

	Treatment[2]						
Species[1]	C	MA	UF	SU	IB	AS	AS/P
Arctostaphylos nevadensis	19	12	-	22	16	1	2
Cercocarpus montanus	25	21	22	22	20	8	10
Penstemon newberryi	38	47	41	43	36	16	20
Purshia tridentata	38	35	32	36	36	14	13
Artemisia tridentata	50	47	43	48	50	43	28
Total	170	162	138	171	158	82	73
Total planted	250	250	200	250	250	250	250
%	68	65	69	68	63	33	29

[1] Arctostaphylos, Purshia and Artemisia planted Luther Pass 03-ED-89 P.M. 2.36. Cercocarpus, Penstemon planted Ward Valley, County Road.

[2] C = control; MA = co-precipitated, co-granulated magnesium ammonium-magnesium potassium phosphate, 7-40-6, coarse granual (MagAmp); UF = urea formaldehyde; SU = sulfur-coated urea; IB = isobutylidine diurea (IBDU); AS = ammonium sulfate, 21-0-0; AS/P = ammonium phosphate-sulfate, 16-20-0; all at 1/2 gm N per plant.

pronounced decrease in transplant survival for all species in both soluble fertilizer treatments with one exception. Ammonium sulfate apparently did not reduce survival of Artemisia tridentata (Fig. IV-4). The reduction in survival with soluble fertilizers was attributed to salinity. Mortality due to excess salts from the soluble fertilizers might have been reduced by deeper fertilizer placement.

Three species, Arctostaphylos, Cercocarpus and Purshia, made little growth during this first growing season, and thus, there were no apparent response to fertilization. It was not determined whether this was because of low nutrient requirements of these species or because of lack of water. The two species which responded to fertilization made best growth at the bottom of the plots (Figs. IV-1, IV-2) indicating that moisture may have been a major limiting factor for growth. Soil moisture samples taken October 4 indicated very dry conditions throughout both plots. Rainfall data taken near the Luther Pass site (Site 2) are given in Table 1 (of the main body of this report). The total precipitation from April 2 through October 6 was 2.90 in. During this period only four storms produced more than 0.2 in. of rain each. These rains were on April 11-14, 0.31 in.; May 12-15, 0.22 in.; July 26-28, 0.23 in. and August 26-27, 1.11 in. Periods of less than 0.2 in. of rain during this time were: 9, 27, 71, 28 and 41 days respectively.

The other two species, Penstemon newberryi at Site #1 and Artemisia tridentata at Site #2, responded to fertilizer applications.

The differences in the slopes of the fertilizer responses of Artemisia (Lines A, B, C, Fig. IV-1) are indicative of the microsite variation between the top and bottom of the cut. The lack of slope and low regression coefficient (-0.34) of the ammonium sulfate treatment (Line B) suggest that this fertilizer is toxic to this species. Differences between the control (Line C) and means of all NPS fertilizers (Line A) are attributed to response to nitrogen, phosphorus and sulfur.

FIGURE IV-1. Effect of position on cut and fertilizer on growth of Artemisia tridentata on Luther Pass, Tahoe Basin 03-ED-89 P.M. 2.

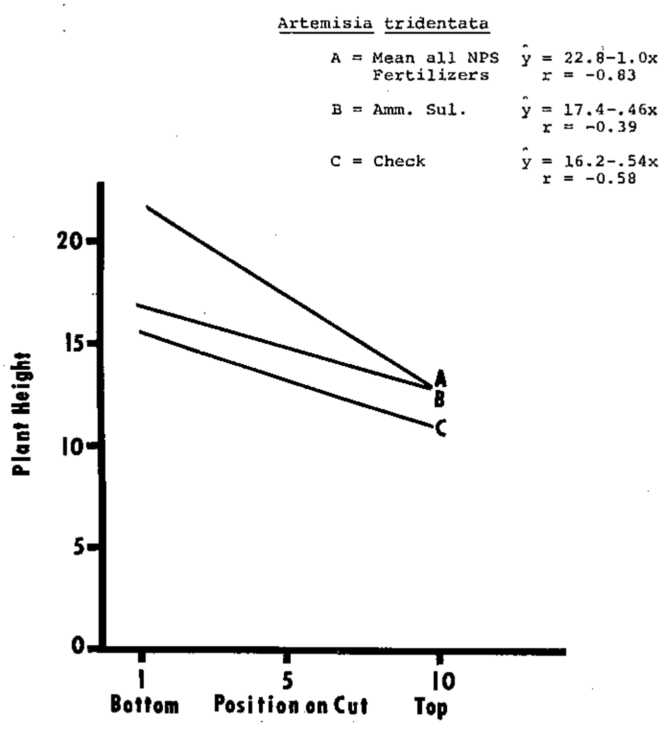
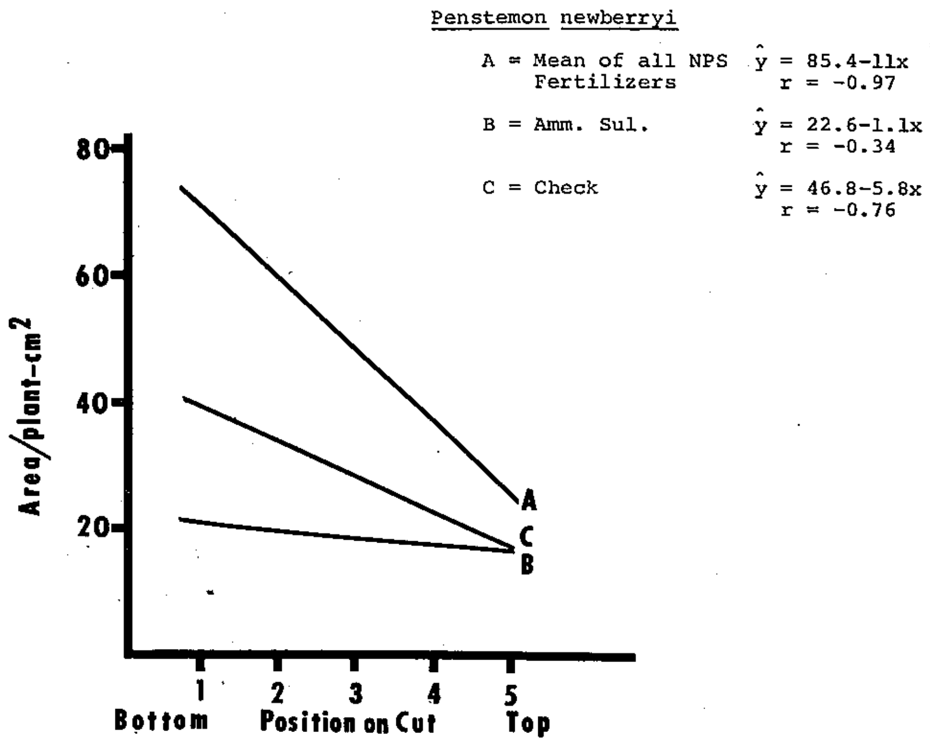


FIGURE IV-2. Effect of position on cut and fertilizer on growth of Penstemon newberryi at Ward Valley, Tahoe Basin.



Responses of Penstemon (Fig. IV-2) were similar for the control and the mean of all NPS treatments with increased response to nitrogen, phosphorus and sulfur at the bottom of the cut compared to the top. Although there was a small overall increase in plant growth in the ammonium sulfate treatment (nitrogen response), the low regression coefficient (-0.39) indicates considerable variation within treatment. The differences between the ammonium sulfate and means of all NPS fertilizers (Lines A and B, respectively) are attributed to response to phosphorus and sulfur.

Growth and survival data for Penstemon newberryi for individual treatments are shown in Figure IV-3. Because of its low spreading habit, growth is expressed as area covered. A transparent overlay was used to determine area. This species made more growth in every fertilizer treatment except ammonium sulfate compared to the control. Plants in these treatments averaged 60 to 100% larger than control plants. These increases were significant at the 95% level for ureaformaldehyde, sulfur-coated urea and ammonium sulfate/phosphate and at the 99% level for MagAmp and IBDU.

Growth and survival data for Artemisia tridentata for individual treatments are shown in Figure IV-4. Growth data for this species is expressed in cms of height because of the upright growth habit. Fertilized plants were 17 to 38% larger than control plants but this response was not significant due to variations within and between replications.

Discussion

Pot tests using species which are sensitive to nutrient deficiencies may show growth response to added nutrients when grown in subsoils from highway cuts. However, because of differences in response of woody species to nutrition and microenvironment (particularly soil moisture),

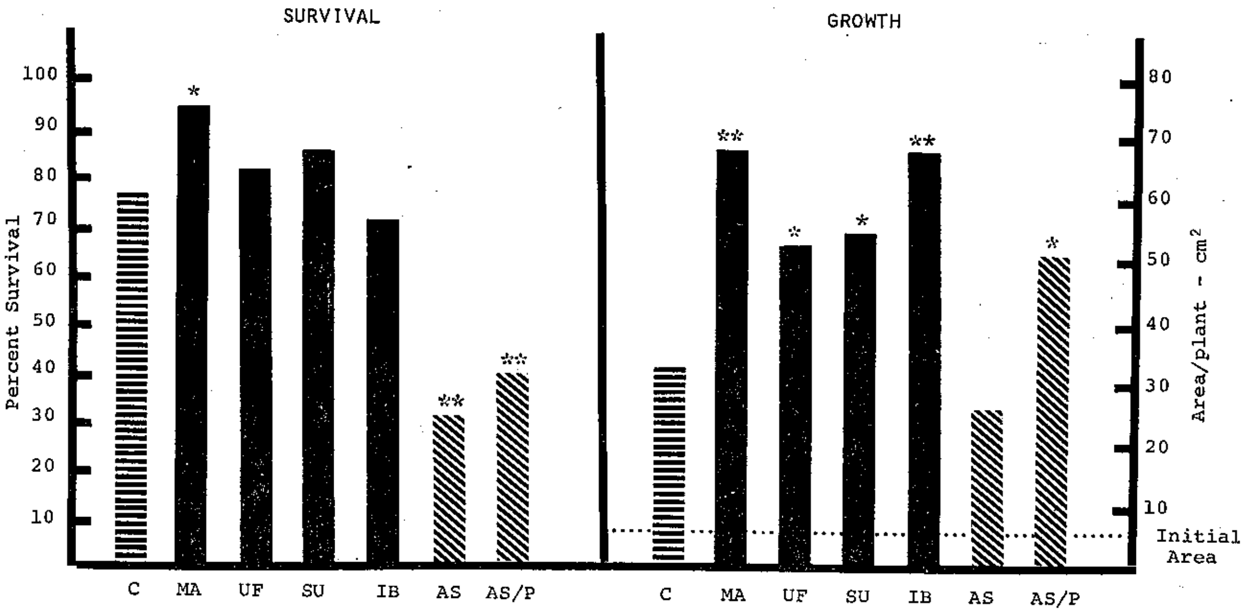


Fig. IV-3. Growth and survival of road cut plantings of Penstemon newberryi as influenced by fertilizer source. Rate of fertilizer application 1/2 gram of nitrogen per plant. Statistical significance compared to the controls indicated for 5 and 1 percent levels of confidence, * and ** respectively.

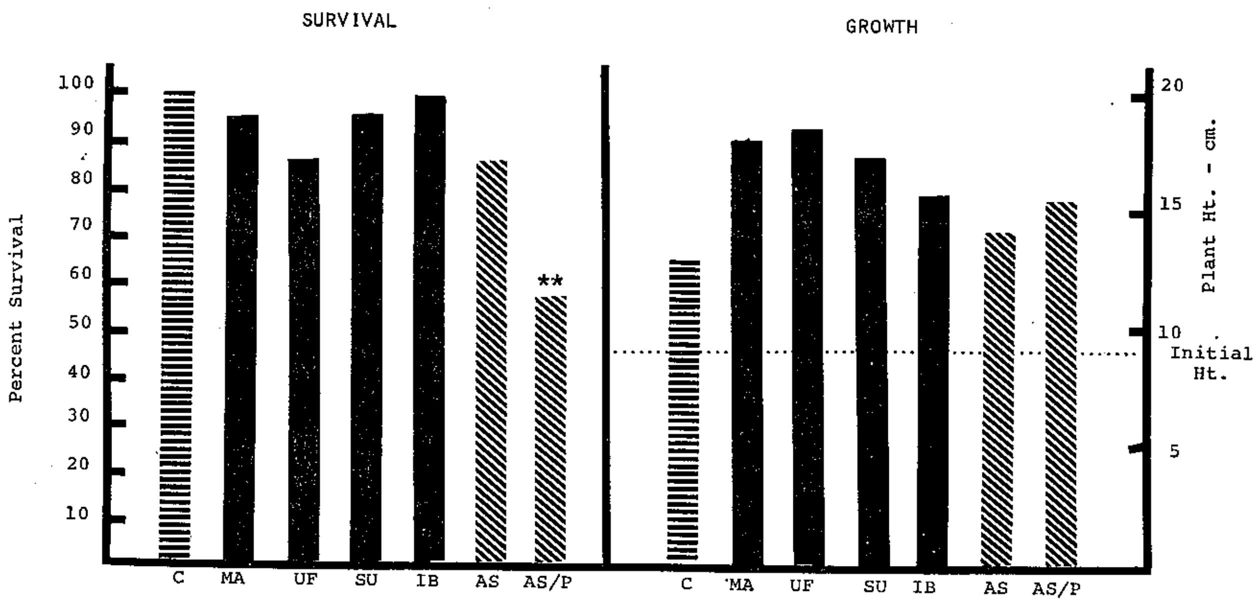


Fig. IV-4. Growth and survival of road cut plantings of Artemisia tridentata as influenced by fertilizer source. Rate of fertilizer application 1/2 gram of nitrogen per plant. Statistical significance of difference from the control at the 1% confidence level indicated by **.

generalizations cannot be made regarding the benefits of fertilization of woody plants in revegetation projects. These limited trials indicate that field trials should be made with individual species to be used on revegetation projects.

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APPENDIX V

Vegetative Propagation of Arctostaphylos nevadensis, Gray, Ceanothus prostratus, Benth., and Penstemon newberryi, Gray[1]

Andrew T. Leiser and James J. Nussbaum[2]

ABSTRACT: Vegetative propagation methods for three high Sierran native plants are described. Arctostaphylos nevadensis, Ceanothus prostratus and Penstemon newberryi are attractive ground-covers suitable for revegetation of disturbed mountain sites or for ornamental use. A. nevadensis roots satisfactorily in outdoor plastic covered frames with bottom heat during the winter months. Although C. prostratus roots well from softwood cuttings, under mist, survival after transplanting is poor. Rooting methods, as for A. nevadensis, gives rooted cuttings which transplant satisfactorily. Survival and growth of both species is enhanced by transplanting into 8 in. deep tubes compared to 2 in. peat pots and by irrigation with 1/2 strength Hoagland's solution instead of tap water (pH 7.8). P. newberryi roots well from softwood cuttings under intermittent mist and cuttings grow well in 2 in. peat pots in a UC type mix.

-------------------------- End of Abstract --------------------------

INTRODUCTION

Vegetative propagation studies on three ground-cover plants, Arctostaphylos nevadensis, Gray, (pine-mat manzanita), Ceanothus prostratus, Benth., (squaw carpet) and Penstemon newberryi, Gray, (mountain pride) were begun because of their potential value for revegetation of high Sierran mountain sites such as the Tahoe Basin. They are also potentially valuable ornamentals for temperate climate areas.

There are reports in the literature on the rooting of some species of Arctostaphylos (e.g. A. uva-ursi) but variation between species suggests that requirements for each species must be determined.

Successful propagation of Ceanothus prostratus has been reported by Ruf (1) and Ticknor (2). Using various media and hormone treatments and intermittent mist, Ruf reported average rooting percentages of cuttings taken on October 1, 1960 of 62; on December 17, 1960 of 33; and on August 11, 1961 of 81. The only transplanting survival reported was for the August 1961 cuttings. Little additional cultural data was given. Ticknor (2) reported wide variability in rooting among more than 50 selections of C. prostratus but did not specify whether differences were due to genetic or physiological (site, shade vs. sun, time of year, etc.) causes. Losses on transplanting led to rooting of cuttings in plant bands (2 x 2") for growing on. He did not give details on the time of year cuttings were taken or other details for developing optimum commercial production methods for this species.

Although many species of Penstemon may be propagated from cuttings or divisions, some are very difficult to propagate vegetatively. Information on vegetative propagation of P. newberryi is not available.

Relatively little is known of the rooting and successful establishment of these three species so a wide spectrum of experiments, using a range of auxin concentration, various media, season, plant source and rooting environment variables have been used.

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[2]Associate Professor and Staff Research Associate, respectively. Department of Environmental Horticulture, University of California, Davis, California.

Results

Cuttings of Arctostaphylos nevadensis have been taken from early summer through November (after snow fall). Results discussed here are given in Table V-1. Some rooting has occurred with softwood cuttings under mist but percentages have been low and survival, after transplanting, has been nearly zero. The best rooting has been with cuttings taken in the fall, rooted in outdoor sweatboxes with bottom heat. All cuttings were drenched with fungicide (1.08 gm Dexon plus 0.76 gm Benlate per gallon).

Two rooting media were used: vermiculite and a 50:50 mix of sphagnum peat and perlite. A total of 2,600 cuttings were stuck in November. The overall rooting percentage was 45.8 (1191 of 2600). The largest difference occurred in rooting media. Only 15.3% (198 of 1300) rooted in the peat-perlite medium compared with 76.5% (993 of 1300) rooting in vermiculite. The highest rooting percentage of 87.5 (525 of 600) resulted with the lower concentration of 1000 ppm IBA and vermiculite medium.

All cuttings were rooted by March and transplanted into 2" peat pots with UC type soil mix (1:1:1, peat:sand:ammoniated redwood sawdust). Plants were watered with a one-half strength Hoagland solution in de-ionized water instead of tap water. Tap water (pH 7.8) was used the previous year and growth and survival was very poor. Watering with Hoagland solution in deionized water resulted in good survival and vigorous growth.

In a transplanting experiment, pine-mat manzanita were transplanted into 8" tar-paper liners (8" x 1 3/4" x 1 3/4") with the following soil mixes: 1) sand + peat, 2) peat + vermiculite, 3) sand, and 4) UC mix (1:1:1; peat:sand:redwood sawdust). The results are shown on Table V-2. There was relatively no difference in survival or growth among the four media with an overall 89.9% survival after 4 months. This compares with 62.7 percent survival in 2" peat pots watered with Hoagland solution in deionized water and nearly zero percent with peat pots watered with tap water. The deep tubes had much better drainage which the manzanita seem to require.

Ceanothus prostratus

Squaw carpet ceanothus has been difficult to root consistently. Data of some experiments are given in Table V-3. In August 1970 squaw carpet cuttings were stuck in perlite medium with no auxin and 1000 ppm IBA. Rooting was doubled with 1000 ppm IBA (53%) compared with 25% with no auxin.

As high as 83% rooting was obtained in July 1971, but cuttings taken just 14 days later did not root well. It appears that certain cuttings from certain plants root much better than others and seasonal variations in rooting potential exist. One experiment which points to this condition was conducted in August 1971. On August 10, cuttings were collected from three locations in the Tahoe Basin. The following rooting resulted: Ward Valley 48%, Tahoma 8%, and South Lake Tahoe 25%. The cuttings were rooted under intermittent mist with ±75° bottom heat, 1000 ppm IBA and a 50:50 mix of perlite and vermiculite medium. Whether the differences were due to inherent genetic differences or to physiological conditions of the cuttings is not known.

Cuttings taken in November 1971 were stuck in an outside sweatbox with 70° bottom heat. Results were as follows:

	Perlite/Peat medium	Vermiculite medium
1000 ppm IBA	16 rooted/600 stuck	229 rooted/600 stuck
2000 ppm IBA	5 rooted/600 stuck	179 rooted/600 stuck

Rooting was not as good as a previous trial the year before. One explanation may be that most of the cuttings were taken from one vigorous plant in Ward Valley. In subsequent experiments during the summer of 1972, the same plant produced only 25 and 30% rooting while other sources produced 50 and 60%.

The highest rooting percentages have been from cuttings taken during the summer and rooted under mist. As in manzanita, survival after transplanting these rooted summer cuttings has been a problem. Survival has been

TABLE V-2. Transplanting Arctostaphylos nevadensis, Gray. Transplanted April 5, 1972, survival August 3, 1972.

Source of cutting[1]	Container	Medium	Number Planted	Survival No.	Survival %
EH 71-303	2" peat pot	UC Mix	50	36	72.0
EH 71-306	2" peat pot	UC Mix	100	58	58.0
EH 71-306	8" liner	UC Mix	66	61	92.3
EH 71-306	8" liner	Sand	66	60	90.9
EH 71-306	8" liner	Peat-vermiculite	24	22	91.6
EH 71-303	8" liner	Peat-vermiculite	90	80	88.9
EH 71-303	8" liner	Sand-peat	66	55	83.3
	2" pot	Total	150	94	62.7
	8" pot	Total	312	278	89.1

[1] EH 71-303 from Bliss State Park, EH 71-306 from Upper Ward Valley.

TABLE V-3. Rooting of Ceanothus prostratus, Benth.

	Treatment		Results				
Date	Medium	Environment	Auxin	Temp.	Number Stuck	Number Rooted	% Rooted
8/17/70	perlite	G.H. Int. Mist	0	±70°F	60	15	25
		G.H. Int. Mist	1000		60	32	53
7/16/71	perlite-vermiculite	G.H. Int. Mist	1000	±75°F	200	166	83
8/10/71	perlite-vermiculite	G.H. Int. Mist - Ward Valley	1000	±75°F	270	130	48
		- Tahoma	1000		131	11	8
		- South Lake Tahoe	1000		346	85	25
11/3/71	peat-perlite	Lath, sweatbox	1000	±70°F	600	16	2.7
			2000		600	5	1
	vermiculite	Lath, sweatbox	1000	±70°F	600	229	38
			2000		600	179	30

very poor with up to 100 percent loss, whereas winter cuttings have been easily transplanted with good survival. Cuttings taken in November 1971, transplanted April 5, 1972 into 8" x 1 3/4" x 1 3/4" tubes had over 98% survival on August 3. Survival was 48 of 50 transplants in the UC type soil mix, 50 of 50 in peat-sand mix and 18 of 18 in peat-vermiculite.

Penstemon newberryi

Penstemon newberryi has been relatively easy to propagate and to grow on to transplanting size. The methods which have been successful are as follows. Softwood cuttings taken in July 1971 from the Donner Summit area, treated with 1000 ppm indolebutyric acid (5 sec. quick dip), rooted in a 50:50 perlite-vermiculite medium under intermittent mist within 10 days. A rooting percentage of 81% (2590-3200 cuttings) was obtained. Rooted cuttings were transplanted to 2" peat pots in the UC type soil mix. Survival and growth were excellent. Transplants were grown under lath in Davis and thrived with tap water (pH 7.8) irrigation. Plants were so vigorous that cuttings could be taken from transplants one month after transplanting.

A second experiment was conducted in July 1972. Softwood cuttings were taken from stock plants grown in Davis and treated with 1500 ppm IBA. They were rooted under the same conditions as the previous experiment except two types of mist water were used. One-third of the cuttings were placed under deionized mist and the others under tap water as in 1971. Rooting approached 100 percent under the deionized water and an overall rooting percentage of 84 percent (1760 of 2100) cuttings was obtained in 14 days.

Conclusions

These experiments have clearly shown that Arctostaphylos nevadensis, Ceanothus prostratus and Penstemon newberryi can be successfully propagated and transplanted. P. newberryi may be propagated throughout the year and easily transplanted into containers. A. nevadensis and C. prostratus have more specific requirements and warrant more research. The source of cuttings, the season cuttings are stuck, the rooting medium, the water quality and the cultural practices following tranplanting are all very critical in good survival and growth of these two species.

TABLE V-1. Rooting of Arctostaphylos nevadensis, Gray.

	Treatment				Results		
Date	Medium	Environment[1]	Auxin[2]	Temp.	Number Stuck	Number Rooted	% Rooted
7/31/70	perlite-verm.	G.H. Int. Mist	1000	±70°F	60	5	8
	perlite-verm.	G.H. Int. Mist	2000	±70°F	60	4	7
	perlite-verm.	G.H. Int. Mist	4000	±70°F	60	7	12
8/17/70	perlite	G.H. Int. Mist	0 (control)	±70°F	80	15	19
			1000	±70°F	80	20	25
11/3/71 (Bliss Park source, EH 71-303)	peat-perlite	Lath, sweatbox	1000	±70°F	300	30	10
			2000	±70°F	300	43	14
	vermiculite	Lath, sweatbox	1000	±70°F	300	263	88
			2000	±70°F	300	237	79
11/10/71 (Ward Valley source, EH 71-306)	peat-perlite	Lath, sweatbox	1000	±70°F	300	57	17
			2000	±70°F	300	60	20
			2000[3]	±70°F	100	14	14
	vermiculite		1000	±70°F	300	262	87
			2000	±70°F	300	166	55
			2000[3]	±70°F	100	65	65

[1]Greenhouse, intermittent mist 5 sec. per 2 min.; plastic covered bench (sweatbox) with bottom heat in a lath house.
[2]ppm IBA
[3]+10 ppm, 2,4,5-T

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APPENDIX VI

Overcoming Seed Coat Impermeability of *Arctostaphylos nevadensis* with Sulfuric Acid

Successful germination of seed of the many species of *Arctostaphylos* has been and remains an uncertain proposition for the nurseryman. Little work of a systematic nature has been reported in the literature; only *A. uva-ursi* has been studied in some detail (Giersbach, 1937). With the increasing demand for *Arctostaphylos* species in landscaping situations, a reliable method of producing seedlings needs to be developed.

The fruit of *Arctostaphylos* contains from 4 to 10 nutlets. Depending on the species, these may be separate or firmly coalesced (Munz and Keck, 1959). With some effort, the nutlets of *A. nevadensis* may be separated from each other. Within each nutlet is a white embryo surrounded by a white endosperm layer. A hard, brown seed coat encloses these structures; it must be rendered permeable before imbibition and germination can occur. Soaking in concentrated sulfuric acid is commonly used to remove the seed coat (U.S. Forest Service, 1948). Soaking techniques and duration have not been precisely described; the work reported here attempts to standardize the sulfuric acid soaking procedure.

Materials and Methods

Six lots of 20 individual nutlets (volume ∿0.5cc) of *A. nevadensis* were selected for treatment. Each lot was representative of the size range of the nutlets of this species. The treatments listed in Table VI-1 were conducted as follows:

1) Control - no treatment.

2-6) 10 ml of concentrated sulfuric acid was added to the nutlets in a 50 ml flask. The flasks were then placed in a Gyrotory shaker and agitated at approximately 150 rpm. At the appropriate time, each flask was removed from the shaker and the acid was withdrawn. Rinsing with 200 ml of deionized water, and draining, followed. Then 20 ml of 0.5 M sodium bicarbonate solution was added to each flask to neutralize the acid. After an agitation period equal to that with the acid, the sodium bicarbonate was decanted. After rinsing with 250 ml of deionized water, and draining, 10 ml of deionized water was added to each flask and 24 hours of agitation followed. A pH reading of this final rinse solution was taken with a Beckman Zeromatic pH meter (Table VI-1) to confirm that neutralization of the acid had taken place.

To determine the effect of the acid on the thickness of the seed coat, each nutlet was cut transversely through its widest part with a scalpel blade. The thickness of the seed coat at its thinnest part, from the outer edge to the endosperm layer (Figure VI-1) was measured through an American Optical Spencer binocular microscope with ocular micrometer. Each division on the scale equalled 80 microns (μ); results are expressed in multiples of this figure.

Results and Discussion

The average thickness of the seed coat in microns for each treatment is given in Table VI-1. Figure VI-2 graphically demonstrates that concentrated sulfuric acid is effective in reducing the seed coat thickness of *Arctostaphylos nevadensis* nutlets. Figure VI-3, in which number of seeds in each size class is plotted, illustrates also the decrease in seed coat thickness with increase in soaking time.

These and other data indicate that three hours or more of agitated soaking in sulfuric acid are necessary to completely remove a part of the seed coat down to the endosperm in some nutlets. Injury to endosperm and the embryo may occur once these structures are exposed to the acid. Yet imbibition will not take place unless enough of the seed coat has been removed. A treatment which removes most or all of the seed coat but does not damage the embryo is desirable. Because the 3-hour treatment reduced the seed coat thickness to 200 μ or less on 90% of the nutlets, while exposing the endosperm on only 20%, it appears to be the optimum method for overcoming the impermeability of the seed coat in *Arctostaphylos nevadensis*.

TABLE VI-1. Relationship of seed coat thickness to soaking time in concentrated sulfuric acid.

	Treatment	Average seed coat thickness in μ	pH of rinse water
1.	Control	480	-
2.	Sulfuric 30 min	272	6.6
3.	1 hr	224	7.7
4.	2 hrs	200	8.0
5.	3 hrs	104	7.9
6.	4 hrs	88	7.5
		Deionized water	6.9

Fig. VI-1. Diagram of typical Arctostaphylos nevadensis seed.

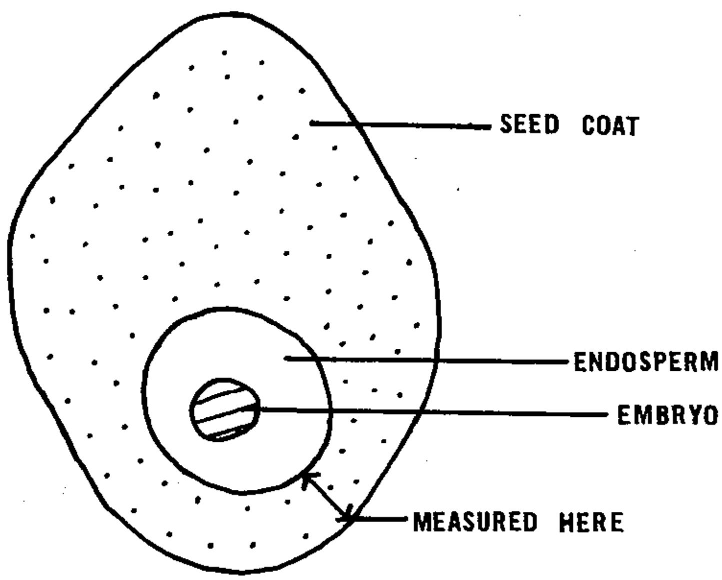


Fig. VI-2. Effect of duration of sulfuric acid soak on seed coat thickness of Arctostaphylos nevadensis.

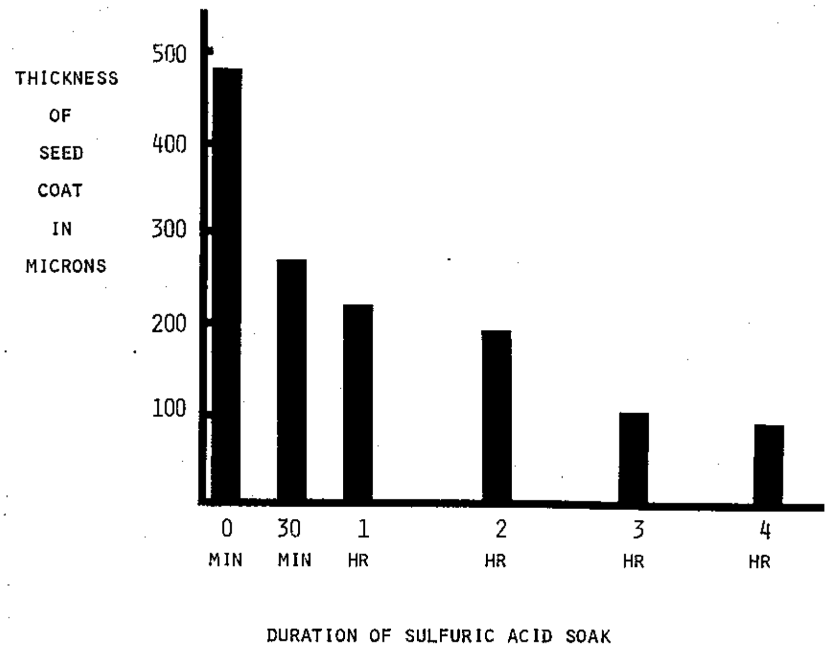
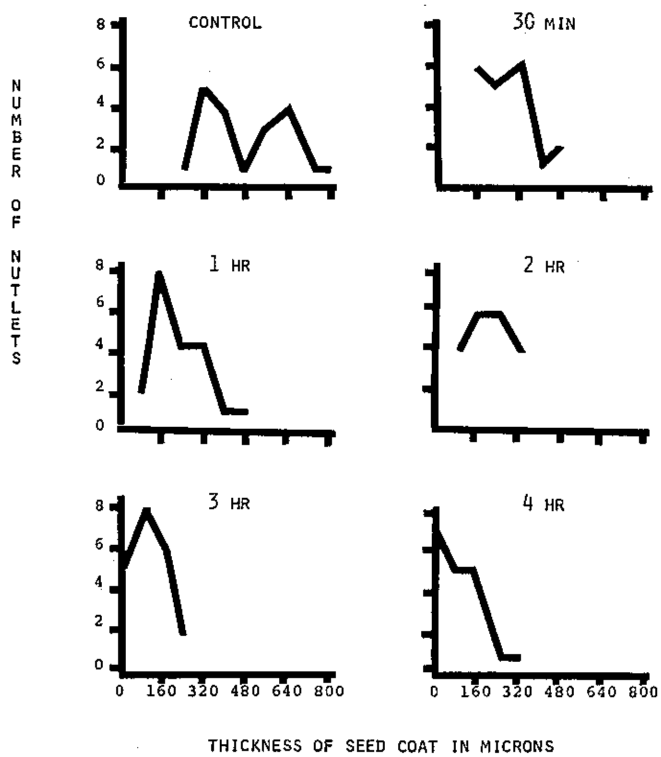


Fig. VI-3. Number of nutlets (seeds) with seed coat thickness by size class (80 micron intervals) after various soaking times in sulfuric acid.



Duration of soaking may vary, but the general technique described here should be useful for other Arctostaphylos species as well.

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APPENDIX VII

KEY TO THE TREES AND SHRUBS OF THE LAKE TAHOE REGION, WITH LEAVES

1. Lvs. scale-like, needle-like, or linear (the Conifers).

  2. The lvs. are appressed to the stem and are scale-like, overlapping like shingles.

    3. Brlts. flattened and arranged in flattened sprays; lvs. 4 at a node, bright green, 1/8 - 1/2 in. long. _Calocedrus decurrens_. Incense cedar.

    3. Brlts. round and arranged in three-dimensional sprays; lvs. 2 or 3 at a node, less than 1/8 in. long. _Juniperus occidentalis_. Western juniper.

  2. The lvs. are free from the stem (although the lf. bases may not be) and are linear or needle-like.

    4. Lvs. borne singly, linear, flattened or ± 4-sided in cross section.

      5. Plant spreading, a low shrub; lvs. 3 at a node, 1/4 - 1/2 in. long. _Juniperus communis_ var. _saxatilis_. Mountain juniper.

      5. Plant upright, a tree; lvs. borne spirally (although sometimes apparently two-ranked).

        6. Lvs. drop leaving rough lf. bases (petiole-like stubs on 3-5 yr. brts.), lvs. spread spirally around stem and are up to 3/4 in. long; _main_ brt. tips pendulous; (cones 1-3 in. long, soft, drop intact). _Tsuga mertensiana_. Mountain hemlock.

        6. Lvs. drop with lf. base leaving ± smooth lf. scars (either smooth and circular or slightly raised and oval); lvs. arranged ± on top of brt. (although originating spirally; _main_ brt. tips horizontal secondary _brts._ often pendulous).

          7. Buds resinous, blunt; lvs. glaucous (with gray lines or bands) above and below; lf. scars round and smooth; (cone erect, cone scales fall while cone is on tree, the true firs).

            8. Lvs. 1 1/4 - 2 1/2 in. long, flattened; (cones 3-5 in. long; bark of old trees gray). _Abies concolor_. White fir.

8. Lvs. (1/2) - 3/4 - 1 1/4 in. long, 4-sided in cross section; (cones 5 - 9 in. long; bark of old trees dark red).
   Abies magnifica. Red fir.

7. Buds not resinous but shiny, brown, pointed; lvs. green above, glaucous only below; (cone 2 - 4 in. long with 3-pronged bracts between the scale, cone dropping intact from tree).
   Pseudotsuga menziesii. Douglas fir.

4. Lvs. borne in clusters or bundles of 2 to 5, semicircular or triangular in cross section (the pines).

9. Bundles contain 5 needles.

10. Lvs. serrulate (on edges, draw needle between thumb and forefinger to feel); cones open when mature.

11. White bands conspicuous on backs of the sharply acuminate lvs.; buds blunt; (cones 10 - 20 in. long, long stalked; mature trees have prominent horizontal brs.).
   Pinus lambertiana. Sugar pine.

11. White bands absent (or inconspicuous) on backs of blunt to acute tipped lvs.; buds sharply pointed (ovid-acute); (cones 5 - 10 in. long, short stalked).
   Pinus monticola. Western white pine.

10. Lvs. entire; cones remain closed when nature (mature trees usually <30' tall, often with several trunks).
   Pinus albicaulis. Whitebark pine.

9. Bundles contain 2 or 3 needles.

12. Lvs. 2 per cluster, 1 - 2 1/2 in. long; cone 1 - 2 in. long.
   Pinus murrayana. Lodgepole pine.
   (syn. P. contorta var. murrayana, P. c. var. latifolia.)

12. Lvs. 3 (occasional clusters with 2) per cluster, 5 - 10 in. long; cones 2 - 10 in. long.

13. Young (1 yr.) brts. glaucous (gray--blue-gray); foliage slightly gray-green; cones 6 - 10 in. long; bark of mature trees has fragrance of vanilla.
   Pinus jeffreyi. Jeffrey pine.

13. Young brts. orange-red; foliage green; cones <6 in. long; bark lacking vanilla fragrance.

14. Orange-red color persists on brs. for an indeterminent number of yrs.; prickles on cone-scales turned inward; cones 2 - 3 in. long; (native only on Mt. Rose, Nev.) Pinus washoensis. Washoe pine.

14. Orange-red color of brts. turning gray in 2 - 3 yrs.; prickles on cone-scales turned outward; cones 3 - 6 in. long; (native mostly below 5,550 ft.) Pinus ponderosa. Ponderosa pine.

1. Lvs. with a definite blade, not scale-like, needle-like or linear.

15. Buds and lvs. opposite (2 at a node).

16. Lvs. compound; twigs stout with large soft pith.

17. Plant usually less than 4' tall; lvs. with 5 lflts., ± acuminate, serrate to ± 3/4 of lflt. length; fls. and fr. in conical clusters; fr. red. Sambucas microbotrys. Mountain elderberry.

17. Plant usually more than 4' tall; lvs. with 3 - 5 lflts., serrate for entire length of lflt; fls. and fr. in flat-topped clusters fr. blue-black. Sambucus caerulea. Blue elderberry.

16. Lvs. simple; twigs slender with narrow pith.

18. Plant prostrate or decumbent (with arching canes, usually <1 1/2' tall.

19. Lvs. thick, leathery, often shiny above, with several coarse teeth on each side; plant usually prostrate and tight to the ground; bark on 2 yr. twigs tight. Ceanothus prostratus. Squaw carpet.

19. Lvs. soft pubescent, not shiny, entire or with shallowly rounded lobes (especially on vigorous young shoots); plant decumbent with long arching shoots which root at the tips; bark on 2 yr. and older brs. shredding. Symphoricarpus acutus. Creeping snowberry.

18. Plants neither prostrate nor decumbent; usually >1 1/2' high.

20. Brlts. (1 yr.) distinctly red; bark on older brs. smooth, tight; lvs. either deeply palmately dissected or with parallel main veins; fls. many in terminal corymbs.

21. Lvs. deeply palmately dissected; brlts. red, older bark gray; lenticels absent; fls. greenish in loose terminal corymbs; fr. a 2-winged samara.
Acer glabrum var. *torreyi*. Mountain maple.

21. Lvs. entire, with parallel main veins; brlts. and 2-yr. bark dark red; fls. white in terminal corymbs; fr. white, fleshy.
Cornus stolonifera. Creek dogwood.

20. Brlts. (1 yr.) tan to brown (red-brown in one), bark on older brs. shredding; lvs. entire or with shallowly, usually irregular, rounded lobes, always with netted veination; fls. axillary in 2's.

22. Lf. margins glabrous, not ciliate; lvs. <1 in. long, elliptic, entire (shallowly lobed on vigorous shoots, puberulent on both surfaces; brlts. reddish-brown; fls pink, axillary, frs. white.
Symphoricarpos vaccinoides. Mountain snowberry.

22. Lf. margins ciliate; lvs. 1 in. or longer.

23. Brlts. hispid; Lvs. obtuse to acute at apex, with bluish cast, 1 - 2 in. long; fls. yellow; fr. blue-black oval, composed of two ovules surrounded by a fleshy sac-like covering.
Lonicera caurina. Mountain fly honeysuckle.

23. Brlts. not hispid.

24. Lvs. 1 - 2 1/2 in. long, acute to obtuse at apex; buds distinctly 4-sided; fls. dark red, axillary; fr. red, apparently two-lobed but actually composed of two ovaries joined along a common side.
Lonicera conjugialis. Double-fruited honeysuckle.

24. Lvs. 2 - 5 in. long, acute to acuminate at apex, buds not distinctly 4-sided; fls. yellow, axillary; fr. black, globose, subtended by reddish bracts 1/2 in. in diameter.
Lonicera involucrata.

15. Buds and lvs. alternate (1 at a node).

25. Lvs. compound.

26. Stems armed (with thorns); lvs. pinnately cmpd.; lflts. 5 - 7 obovate, 1 - 1 1/2 in. long, serrate; fls. pink; fr. orange-red.
Rosa _woodsii_ var. _ultramontana_. Mountain rose.

26. Stems unarmed.

27. Lvs. palmately cmpd.; lflts. pubescent, usually 5, less than 3/8 in. long with revolute margins; fr. a dry capsule.
Potentilla _fruticosa_. Shrubby cinquefoil.

27. Lflts. 7 or more, without revolute margins; fr. fleshy.

28. Lvs. with 7 - 9 lflts., usually 9, coarsely serrate; stems of terminal growth glaborous; fl. and fr. cluster with less than 80 members, $\pm$ convex; fr. coral red.
Sorbus _californica_. California mountain-ash

28. Lvs. with 9 - 13 lflts, usually 13, coarsely to finely serrate; stem of terminal growth pubescent; fl. and fr. cluster with more than 80 members, flat-topped; fr. orange-red.
Sorbus _scopulina_. Western mountain-ash.

25. Lvs. simple.

29. Stems armed (thorny or spiny).

30. Spines are small stiff, sharp pointed brlts, usually 1 in. or more long; lvs. glaucous, entire, prominently 3-veined on the underside; fls. small, creamy white, in dense clusters; fr. a capsule with dehiscent cap.
Ceanothus _cordulatus_. Mountain whitethorn.

30. Spines are true thorns at nodes or internodes (not sharp-pointed brts.), <1 in. long. (fls. not white; fr. is fleshy).

31. Lvs. 1 - 4 in. in diameter, deeply palmately dissected into 3 - 5 coarsely toothed lobes; (fls. yellow; fr. purple smooth).
Ribes _divaricatum_ var. _inerme_.

31. Lvs. <1 in. in diameter.

32. Brlts. prickly on internodes; lvs. cordate at base, pubescent on both surfaces; fls. yellow; fr. red, bristly.
Ribes montigenum. Mountain gooseberry.

32. Brlts. prickly or spiny only at nodes.

33. Lvs. glandular on both surfaces, margin ciliate, (orbicular, to 3/4 in. in diameter, shallowly cleft; fls. yellow; fr. dark red, smooth).
Ribes leptanthum var. lasianthum. Alpine gooseberry.

33. Lvs. puberulent but not glandular, margin not ciliate, (ovate 1/2 in. in diameter, deeply cleft into 3 - 5 lobes; fls. maroon with white; fr. red to maroon with stiff spines).
Ribes roezlii. Sierra gooseberry.

29. Stems unarmed.

34. Plants, lvs. and sometimes brlts., silvery or whitish.

35. Foliage distinctly pungently aromatic.

36. Lvs. 3-lobed at least in part, each lobe pointed; lvs. cuneate, 1/2 - 2 in. long, lvs. and new growth densely canescent; ± pleasant aroma of sage; fls. in terminal spikes, flowering in mid-summer.
Artemisia tridentata. Big basin sagebrush.

36. Lvs. not 3-lobed, very narrow with parallel sides, 1 - 2 1/2 in. long; brlts. and lvs. covered with white felt-like tomentum; ± unpleasant aroma; (fls. in late summer, yellow, daisy-like in terminal clusters; snowy white seed heads).
Chrysothamnus nauseosus. Rabbit brush.

35. Foliage not distinctly pungently aromatic, buds tightly appressed to stem.

37. Lvs. very narrow with nearly parallel sides (± linear) to 3 1/2 in. long; brlts. and lvs. covered with silky pubescence, often with a reddish cast.
Salix exigua var. exigua. Narrow-leaf willow.

37. Lvs. narrowly lanceolate, or elliptic to broadly oblanceolate, sides not parallel.

38. Brlts. and buds white; lvs. narrowly lanceolate to oblanceolate, to 1 1/2 in. long, sily pubescent.
Salix geyeriana var. *argentea*. Silver willow.

38. Brlts. and buds yellow to red; lvs. broadly oblanceolate to elliptic, to 2 1/2 in. long, ± tomentose but not silky.
Salix eastwoodiae. Eastwood willow.

34. Plants (lvs.) green, blue-green or grayish-green.

39. Lvs. mostly entire to sparingly toothed. (See 39, p. 9.)

40. Lvs. bluish-green or grayish-green.

41. Lvs. glabrous, glaucous, (about 1/2 - 1 in. long, ovate to obovate; fr. a berry; plant compact to 2 ft. tall).
Vaccinium occidentale. Western blueberry.

41. Lvs. pubescent on both surfaces.

42. Lvs. elliptic to obovate, to 2 1/2 in. long, (greater than 1 1/2 in.); margin entire (though gland tipped); buds red.
Salix commutata. Mountain willow.

42. Lvs. very narrow with nearly parallel sides (± linear), to 3 in. long, entire to sparingly toothed; buds green to whitish.
Salix exigua var. *exigua*. Narrow-leaf willow.

40. Lvs. green (not bluish or grayish-green).

43. Bark on brs. reddish-brown, smooth or sometimes flaky.

44. Lvs. oblanceolate to elliptic, ± mucronate, usually <1 1/2 in. long; brlts. very flexible (± vine-like); plant sprawling to prostrate, less than 2 ft. high at maturity; fls. white.
Arctostaphylos nevadensis. Pinemat manzanita.

44. Lvs. elliptic, 1 - 2 in. long; brlts. stiff; plant erect, more than 2 ft. at maturity; fls. pink.
Arctostaphylos patula. Greenleaf manzanita.

43. Bark on brs. not reddish brown.

45. Margins of lvs. revolute.

46. Lvs. 2 - 3 in. long, thin, oblanceolate to obovate, dull green below; buds with a single bud-scale; (brlts. green to red, pungent when broken; bark smooth gray; fls. and fr. in catkins).
Salix scouleriana. Scouler's willow.

46. Lvs. usually less than 1 1/4 in. long, thick and leathery, lanceolate to narrowly elliptic.

47. Foliage aromatic when crushed, lvs. mainly at the ends of brts., undersides with yellow glands; fls. white in terminal clusters.
Ledum glandulosum var. *californicum*. Western Labrador tea.

47. Foliage not aromatic, margin of lvs. strongly revolute, undersides tomantose with a prominent mid-vein and without yellow glands; (brlts. dark red; fr. with a characteristic plumose style to 3 in. long).
Cercocarpus ledifolius. Curl-leaf mountain mahogany.

45. Margins of lvs. not revolute.

48. Lvs. densely yellow-tomentose beneath, 1 - 3 in. long; fr. spiny.
Castanopsis sempervirens. Bush chinquapin.

48. Lvs. whitish beneath.

49. Reflective silvery tomentum on lower side of lvs.; (lvs. 1 - 4 in. long, linear to oblanceolate, dark green and shining above; fls. and frs. in catkins).
Salix sitchensis var. *angustifolium* (*S. jepsonii*). Jepson willow.

49. Reflective tomentum absent on lower side of lvs.

50. Lvs. oblong to ovate, 3/4 - 2 in. long, whitish to green beneath; buds with several imbricate scales; (brlts. stiff, brown; fr. an acorn; may rarely be a small tree).
Quercus vaccinifolia. Huckleberry oak.

50. Lvs. narrowly lanceolate to oblanceolate to 3 in. long; buds with single bud scale.

51. Brlts. glabrous, shiny, reddish-brown; lvs. thin, often bronzy when young.
Salix lemmonii. Lemmon willow.

51. Brlts. puberulent, dull brown; lvs. thick, leathery.
Salix lasiolepis. Arroyo willow.

39. Most lvs. definitely toothed or lobed.

52. Lvs. lobed.

53. Lobes obscure, lvs. orbicular, glandular-sticky, 1/2 - 1 1/2 in. in diameter; brlts. gray-brown; infl. few-flowered; fls. light pink or white; fr. red.
Ribes cereum. Squaw currant.

53. Lobes distinct.

54. Lvs. glandular-pubescent, 3-lobed, dissected, 1 - 2 in. in diameter; brlts. with reddish shreddy bk.; fls. greenish-purple; fr. blue-black, glandular-bristly; plant low, with spreading brs.
Ribes viscosissimum. Sticky currant.

54. Lvs. not glandular pubescent.

55. Size of lvs. <1 in. long, lvs. cuneate, 3-lobed, pubescent above, tomentose beneath with revolute margins; (fls. yellow).
Purshia tridentata. Antelope brush.

55. Size of lvs. >1 in. long; lvs. in outline, cordate with 3 - 5 lobes.

56. Lobes rounded; stems woody, lenticels prominent on older wood; lvs. 1 - 3 in. in diameter; (fls. bright pink, small, many in a cluster; fr. blue-black, with a waxy bloom).
Ribes nevadense. Mountain pink currant.

56. Lobes pointed; stems herbaceous at tips, lenticels absent; lvs. 2 - 5 in. in diameter; (fls. white, 1 in. or more in diameter, few in a cluster; fr. red, fleshy, many celled).
Rubus parviflorus. Thimbleberry.

52. Lvs. not lobed.

57. Teeth (serrations) fine, each tooth <1/16 in. long.

58. Lvs. pungently aromatic, upper surface shiny, ± sticky; each tooth with a horny gland; (fls. white in terminal clusters; fr. a capsule with dehiscent cap).
Ceanothus velutinus. Snowbrush.

58. Lvs. not pungently aromatic (except Prunus emarginata); teeth without horny glands.

59. Lenticels conspicuous; lvs. elliptic to obovate, 1 - 2 in. long (lvs. with a mild almond aroma when lightly crushed); brlts. reddish-brown, bitter to taste; fls. white, snowy; fr. red, shiny.
Prunus emarginata. Bitter cherry.

59. Lenticels inconspicuous or lacking.

60. Brlts. uniformly dark red; (veins on underside lvs. pubescent, lvs. oblong to oblanceolate, 1 - 2 in. long; fls. greenish-yellow; fr. a black berry).
Rhamnus rubra. Sierra coffeeberry.

60. Brlts. not uniformly dark red.

61. Both surfaces of lvs. pubescent (broadly oblanceolate to elliptic, to 2 1/2 in. long, very finely serrate to entire; brlts. and buds yellow to red.
Salix eastwoodiae. Eastwood willow.

61. Both surfaces of lvs. glabrous.

62. Lvs. thick, leathery; buds with several imbricate scales; lvs. 1 - 3 in. long, lvs. elliptic to broad lanceolate; fls. white in pendulous clusters; fr. a 5-parted dehiscent capsule.
Leucothoe davisiae. Sierra laurel.

62. Lvs. thin, soft; buds with a single bud scale.

63. Petiole with 2 glands at base of leaf blade; lvs. glandular-serrate, glaucous beneath; brlts. yellow, shiny; (lvs. long acuminate, 2 - 4 (to 7) in. long).
Salix lasiandra. Western black willow.

63. Petiole without glands; lvs. not glandular-serrate, not glaucous beneath; brlts. green to red, not shiny; (lvs. 2 1/2 - 3 1/2 in. long, acuminate).
Salix rigida. Brittle willow.

57. Teeth (serrations) coarse, each tooth >1/16 in. long.

64. Lvs. doubly toothed, *i.e.* each tooth crenate and serrate, (1 1/2 - 4 in. long; *fr.* a woody conelet).
Alnus tenuifolia. Mountain alder.

64. Lvs. with simple teeth.

65. Bark on brlts. shredding, lenticels never prominent.

66. Lvs. essentially glabrous, (about 1 in. long; fls. pink in flat-topped terminal clusters).
Spiraea densiflora. Mountain spiraea.

66. Lvs. pubescent.

67. Teeth 3 - 5 per side extending to middle or below; lvs. ovate to obovate, 3/8 in. long; infl. 1 - 3 1/2 in. long.
Holodiscus boursieri. Mountain creambush.

67. Teeth 2 - 3 per side, only near tip; lvs. obovate to cuneate, 1/4 - 1/2 in. long; infl. 1 - 1 1/2 in. long.
Holodiscus microphyllus. Littleleaf creambush.

65. Bark on brlts. tight, not shredding; (lenticels prominent on some).

68. Lvs. 2 - 7 in. long; ovate to cordate, acute; buds sticky-resinous; (plant a large tree with rough gray bark). Populus trichocarpa. Black cottonwood.

68. Lvs. 3/4 - 3 in. long, never truncate or cordate at base; buds not sticky - resinous; if a tree, bark is smooth, creamy white.

69. Petiole distinctly flattened, petiole 1 1/2 - 2 in. long, margin of lvs. ciliate; lvs. round to rhombic; 1 - 3 in. long; plant a tree with creamy white bark. Populus tremuloides. Quaking aspen.

69. Petiole round, not flattened; lvs. oblong, oval, elliptic or ovate, never rhombic; plant is shrubby.

70. Lvs. thick, leathery, oblong to ovate, 3/4 - 1 1/4 in. long, entire, or coarsely and irregularly serrate on upper part of leaf; (brlts. brown; fr. an acorn). Quercus vaccinifolia. Huckleberry oak.

70. Lvs. thin, soft, oval to elliptic, 3/4 - 2 in. long, regularly serrate; brlts. dark red to brown usually with white lenticels; fr. purplish, a berry-like pome.

71. Brlts. and lvs. pubescent. Amelanchier pallida. Western service-berry.

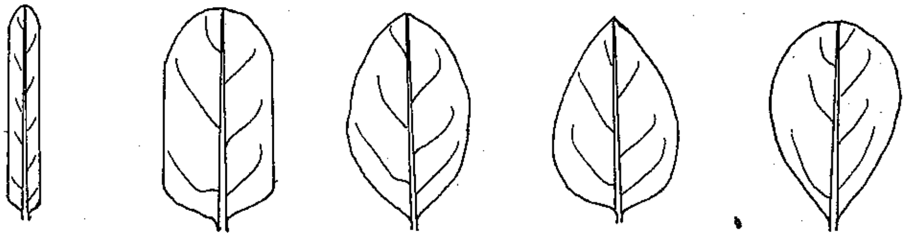
71. Brlts. and lvs. glabrous, lvs. 1 1/4 - 2 in. long. Amelanchier pumila. Smooth service-berry.

Abbreviations Used in Key

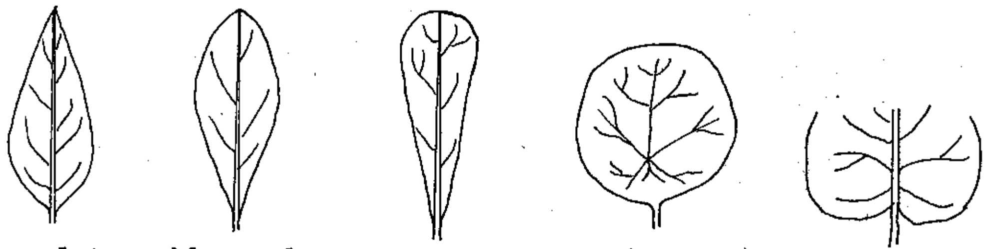
brlts.	- branchlets	frs.	- fruits
brs.	- branches	lf.	- leaf
brts.	- branchlet	lfts.	- leaflets
cmpd.	- compound	lvs.	- leaves
fl.	- flower	<	- less than
fls.	- flowers	>	- greater than
fr.	- fruit	$\pm$	- more or less

TERMS ILLUSTRATED

LEAF SHAPE



linear oblong elliptic ovate obovate

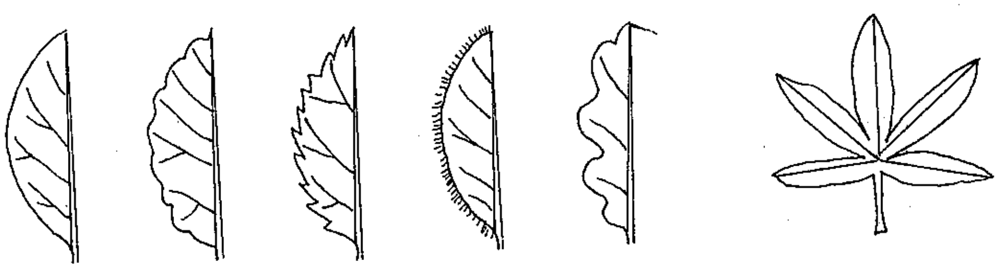


lanceolate oblanceolate cuneate orbicular leaf base cordate

LEAF APEX

acute acuminate mucronate blunt or rounded

LEAF MARGIN



entire crenate serrate ciliate lobed palmately dissected

A6

GLOSSARY

Terms

alternate -- one leaf or lf. scar at a node.

apex -- tip.

appressed -- flattened, as against the stem (e.g. buds, lvs.) or leaf surface (e.g. hairs).

axillary -- arising at a node, in the axil of a leaf - upper angle between petiole or peduncle and stem.

bark -- tough outer layer of a stem or branch (dead phloem).

berry -- a fleshy or pulpy fruit with few to many seeds, e.g. tomato (Note: Blackberry, Strawberry are not true berries).

bract -- a leaf-like structure associated with an inflorescence or a flower (cone).

branchlet -- a small branch or young shoot, usually current seasons wood; sometimes 2 yrs. growth.

bud -- a small axillary or terminal protuberance from the stem which is an undeveloped shoot.

bud scale -- outer covering(s) of a dormant bud.

bundle scars -- small dots or lines found within a leaf scar, marking the point where the vascular tissue entered the leaf petiole from the stem.

catkin -- a thin, compact cluster of usually unisexual flowers.

cleft -- divided half-way.

cone -- a woody fruit (of a conifer), composed of seed-bearing scales.

conical -- cone-shaped.

convex -- rounded outwardly.

evergreen -- remaining green in its dormant season.

decurrent -- running down the stem, as a leaf or leaf base may be attached to and extend down the stem.

dissected -- deeply divided into many narrow segments.

deciduous -- falling, as in the leaves of non-evergreen trees and shrubs.

flexuous -- zig-zag, wavy.

foliaceous -- leaf-like, particularly of flower parts.

gall -- a swelling of plant tissue (caused usually by insects).

glabrous -- without hairs.

gland -- a small secreting structure or area.

glaucous -- covered with a gray or bluish waxy bloom.

globose -- round.

herbaceous -- not woody.

hispid -- with stiff or bristly hairs.

hoary -- covered with white down (hairs).

inflorescence -- flower cluster.

internode -- region between two nodes.

leaf scar -- a scar left on a twig where a leaf detaches.

lenticel -- a small corky spot on the bark.

margin -- edge.

mounded -- low and rounded.

naked -- not covered, or, lacking bud scales.

node -- place of attachment of a leaf to the stem.

opposite -- two leaves or lf. scars at a node.

orbicular -- circular in outline.

pendent -- hanging.

persistent -- remaining attached.

petiole -- stalk of a leaf.

pith -- spongy tissue in the center of a stem.

plumose -- feathery.

prickle -- a small, sharp outgrowth from the bark or epidermis.

procumbant -- trailing or lying flat but not rooting.

prostrate -- lying flat upon the ground (decumbant, etc.).

puberulent -- minutely pubescent.

pubescent -- covered with short, soft hairs.

pungent -- with a sharp odor (acrid to taste).

resinous -- sticky.

revolute -- rolled downward (toward lower side) and back from the margin.

scabrous -- rough to the touch.

sessile -- without a stalk, directly attached.

silky -- covered with appressed, fine, straight hairs.

spike -- a thin, elongated inflorescence with sessile flowers.

stalked bud -- bud attached on a short stem (not sessile).

stipule -- a small, leafy structure at the base of the petiole.

stomatal line -- line of small "breathing" pores on a leaf marked by glaucous exudate.

straggly -- spreading irregularly.

style -- the more or less elongated portion of the female flower parts between ovary and stigma.

superposed -- one above the other.

terminal -- occurring at the tip.

thorn -- a stiff, sharply pointed structure.

tomentose -- with tomentum; dense by wooly or pubescent; with matted soft wool-like hairiness.

trunk -- the main stem of a tree.

twig -- a small branch, without leaves (cf. branchlet) - 1 year portion.

valvate -- with two bud scales meeting at the edges and not overlapping.

vein -- the conducting tissue of a leaf.

venation -- the pattern or arrangement formed by the veins.

villous -- with long, soft, usually curved or curly hairs.